# PUBLIC ROADS

A JOURNAL OF HIGHWAY RESEARCH

UNITED STATES DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS

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Sixty Per Cent of All Motor Vehicles Are Owned in Cities

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U. S. DEPARTMENT OF AGRICULTURE

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# URBAN ASPECTS OF HIGHWAY FINANCE[1]

**By JACOB VINER, Professor of Political Economy, University of Chicago**

*This study of the problems connected with the financing of highways which affect most closely and peculiarly the governments and residents of urban communities was made especially for and under the auspices of the Highway Research Board of the National Research Council. In 1924 a committee of the National Tax Association, of which Professor Viner was a member, presented a comprehensive report on the problems of financing rural highways, but in accordance with its instructions it excluded consideration of the specially urban aspects of the problem from its study.*

*The present study is, therefore, in a sense a supplement to the former one and deals only with problems not considered previously. The report of the study is divided into three parts, of which the first, dealing with the special interests of cities and urban motor-vehicle owners in the highway finance policies and practices of State and county governments, is published in this issue. The second, dealing with the methods and problems of urban highway finance, and third, dealing with certain financial aspects of the traffic-congestion problem, will be presented in a future issue.*

THE tremendous growth in recent years of motor transportation has made necessary a great increase in expenditures for rural highways. Such expenditures for the United States as a whole now approximate $1,000,000,000 annually, and appear to be stabilized for the time being at this level. To a large and growing extent the funds for these expenditures are obtained by the special taxation of motor vehicles, in the form of Federal excise taxes on motor vehicles and parts, passed on in part in the form of Federal aid to the States for highway purposes, and of State motor-vehicle license and fuel taxes. In 1924 the special taxation of motor vehicles produced revenues equal to about 45 per cent of the total expenditures of the country as a whole for the construction and maintenance of rural highways, exclusive of interest on highway indebtedness,[2] and the percentage has been steadily rising each year. It will in all probability reach 50 per cent in 1925.

The Federal excise taxes and the State motor-vehicle license and fuel taxes within each State apply equally to automobiles of the same class regardless of whether they are owned and used in cities or in rural areas. The other sources of rural highway revenues are predominantly State and county ad valorem taxes on general property and bond issues, and the bond issues will in the main be redeemed with funds derived from property taxation or from special taxes on motor vehicles. State and county levies on general property are, with only two exceptions of importance,[3] applied to urban and rural population at uniform rates within each taxing district, and in these two instances the rates are higher on urban than on rural property.[4] It follows that urban dwellers and urban vehicle owners make the same contribution per unit of property and per vehicle of the same class to the cost of financing rural highways as do rural dwellers. It is possible from available data to estimate roughly the relative amounts contributed to the costs of rural highways in the form of motor-vehicle taxes by rural and urban vehicle owners.

#### URBAN-OWNED MOTOR VEHICLES 60 PER CENT OF TOTAL

The Federal census for 1920 shows that on January 1, 1920, there were 2,285,531 automobiles and trucks on farms.[5] The total registration of motor vehicles for the country as a whole in the course of 1919 was 7,565,446, and in the course of 1918 was 6,146,617.[6] Assume that one-seventh of the vehicles registered in 1918, or 878,088, were scrapped during 1919. This would make the number of vehicles in existence on January 1, 1920, 6,687,358, or the registrations during 1919 minus the number scrapped during 1919. On this basis the proportion of urban to total vehicles on January 1, 1920, was approximately 66 per cent. Some allowance should be made, however, for automobiles owned by rural dwellers who are not farmers and by residents in villages and small towns properly to be included as part of the rural area. It is estimated that this would reduce the percentage of urban-owned to total vehicles to 60 per cent, and it would be inferable that urban vehicle owners contributed in about the same proportion to the motor vehicle tax revenues.

To obtain an exact figure, further corrections would have to be made. The average motor-vehicle tax paid per vehicle is much greater for trucks than for passenger cars,[7] and on January 1, 1920, only 6 per cent of the motor vehicles on farms were trucks,[8] as compared to 11.7 per cent of the registrations in 1919 in the United States as a whole.[9] Variations in tax rates combined with variations in percentages of urban to total vehicles as between different States, possible variations in the average payments of gasoline taxes between rural and urban vehicles owing to different annual mileage per vehicle of these two classes of vehicles, and possible variations in the average license fees paid by rural and urban passenger cars because of differences in the type of vehicle commonly owned by rural and urban dwellers, respectively, are further factors affecting the estimate here made of the proportion of the motor vehicle tax revenues paid by urban-owned vehicles. These factors, however, probably tend in the aggregate to increase rather than decrease the proportion contributed by urban vehicle owners. If there has been no substantial change since 1920 in the proportions of rural to urban vehicles, the estimate of 60 per cent as the proportion of motor vehicle tax revenues contributed by urban vehicle owners is a conservative minimum estimate. On this basis of calculation, urban motor-vehicle owners contributed approximately

[1] Part of a report presented by the writer before the annual meeting of the Highway Research Board, National Research Council, at Washington, D. C., December 3, 1925.

[2] National Automobile Chamber of Commerce, Facts and Figures of the Automobile Industry, 1925 edition, p. 49.

[3] Minnesota and North Dakota.

[4] There are often substantial differences, however, between the ratios of assessed to true value for urban and rural property, respectively, with the result that the effective rates are different though the nominal rates are equal. Whether for the country at large such differentiation in assessment ratios operates in favor of or against urban property it is impossible to decide from the scanty evidence available.

[5] Fifteenth Census of the United States, Vol. V, p. 514.

[6] National Automobile Chamber of Commerce, Facts and Figures of the Automobile Industry, 1925 edition, p. 5.

[7] A comparison for 1924 for 28 States, made by Dr. Henry R. Trumbower, showed an average license fee of $10.70 per passenger car as compared to $21.90 per truck. (Proceedings of the Fourth Annual Meeting of the Highway Research Board, 1925, p. 86.) As trucks ordinarily consume more gasoline per mile than do passenger cars, the contribution to gasoline taxes is also probably greater per car for trucks than for passenger cars.

[8] Fifteenth Census of the United States, Vol. V, p. 514.

[9] Facts and Figures of the Automobile Industry, 1925 edition, p. 4.

$260,000,000 in motor-vehicle taxes to the financing of rural highways in 1924.

### URBAN USE OF RURAL HIGHWAYS

It is protested in many quarters, and especially by municipal officials, that this is an inequitable situation and that urban dwellers should not be required to pay the bulk of the costs of rural highways, especially since rural dwellers make little or no direct contribution to the costs of urban streets. The volume of protest is steadily growing, and, as will be shown later, it has already resulted in some States in a measure of reorganization of the highway finance relations of State and city, and county and city governments. Defense of the maintenance of the existing relationship is most conspicuous on the part of the motor interests. They oppose any diversion of highway revenues from the State or county treasuries to the municipalities on the grounds that: (1) It would tend to retard the State and county programs of highway construction and maintenance; (2) the highway improvement program of cities is less elastic and flexible than the rural highway program, and the cities will procure funds by some means or other to carry out at least the major elements of their programs; and (3) the transfer of highway revenues from the State and county treasuries to the municipalities will not relieve the urban motor-vehicle owners as such of any special tax burdens which they already bear, since urban streets are now financed only to a negligible degree by special municipal taxation of motor vehicles. These arguments, and especially the first two, have a considerable measure of validity, but they appeal to reasons of expediency and not to the fundamental equities in the situation.

To the protest that it is inequitable that urban property owners and urban motor-vehicle owners should be forced to contribute to the cost of rural highways at the same rates per unit of property or per vehicle as rural property or vehicles, while, on the other hand, rural property and rurally owned motor vehicles are not required to make any direct contribution to the costs of city, a more cogent reply could be made if it could be demonstrated that traffic on rural highways consists predominantly of urban vehicles, whereas but a slight percentage of the traffic on city streets consists of rural vehicles. Statistical data on these points appear to be sadly lacking. Of the many city traffic surveys which were examined, there was not one which attempted an estimate of the percentage of motor traffic on city streets which consisted of foreign vehicles. Municipal highway officials who were consulted confirmed, however, the common impression that the great bulk of the traffic on the streets of the large cities consists of local vehicles, and that the percentage of rural vehicles on the streets of great cities is at any one moment negligible.

For the percentage of urban vehicles on rural highways the lack of statistical data is almost as complete. A test count made in 1922 on the rural highways of Davidson County, Tenn., in which county Nashville is situated, showed that 70.4 per cent of the vehicles were city owned as compared to 29.6 per cent owned in the country. An inquiry made under the same auspices indicated that the annual mileage per vehicle on rural highways was for urban-owned vehicles 40 per cent that of rural-owned vehicles.[10] The percentage of urban vehicles to total vehicles on the rural highways should be higher in the immediate neighborhood of cities than on portions of the rural highway system distant from any city. On the other hand, the annual mileage of urban vehicles on rural highways should be greater for vehicles owned in the smaller cities than for vehicles owned in the great cities, where the mileage of street pavements is greater and access to the rural highways is ordinarily more difficult.

The Davidson County, Tenn., data can not be applied, therefore, to the metropolitan problem without important qualification, but they do indicate that a substantial fraction of the traffic on rural highways consists of urban-owned vehicles.[11] Confirmation is supplied by the results of an earlier test made on the rural highways of Iowa, which has no large cities. On these rural highways test counts indicated that intracounty traffic from town to town plus circle traffic from town into country and back to town was 30.4 per cent of the total traffic. To obtain the total percentage of the traffic which consisted of urban cars it would be necessary to add (1) urban vehicles going from town to farm, urban vehicles going from farm to town, (2) and urban vehicles on longer trips crossing county and State boundaries, for which data were not separately gathered.[12] Search for further data on this point was unproductive of results.

### TRAFFIC COUNTS SUGGESTED AS BASIS OF COST APPORTIONMENT TO RURAL AND URBAN USES

If the principle be accepted that the costs of financing rural highways should be borne by the users thereof and should be apportioned among the different classes of users in proportion to their use thereof, urban and rural motor vehicles should contribute to the costs of rural highways in the proportions of their respective average annual mileages on such highways. It would probably be impossible in practice to secure comprehensive and unbiased mileage data of this character if it were to be used as a basis for the apportionment of motor-vehicle taxes, but the same purpose could be adequately served if at periodic intervals traffic counts were made on rural highways to ascertain the relative proportions of urban and rural traffic and the costs of rural highways were met from motor-vehicle taxation apportioned to urban and rural areas accordingly.[13] If it were disclosed by such traffic counts that the relative use of rural highways by rural and urban vehicles was substantially different from their relative contributions to motor vehicle tax revenues, adjustment should not be made by differentiating in the rates of State taxation as between urban and rural

[10] University of Tennessee Engineering Experiment Station, "Highway Economics and Highway Transport in Typical Counties of Tennessee," 1922, p. 19.

[11] The study of traffic on the highways of Cook County, Ill., recently made by the Bureau of Public Roads and the Cook County Highway Department shows that the great bulk of traffic on the county highways is produced by Chicago and towns located within 5 miles of the city limits. The report of this study will be published shortly by the Cook County Highway Department.—*Ed.*

[12] T. R. Agg, "Traffic on Iowa Highways," Bulletin 56, Iowa State College of Agriculture and Mechanical Arts, Engineering Experiment Station, Jan. 21, 1920.

[13] Though contrary opinions have been expressed, a count of the relative numbers of vehicles of different types which pass the counting stations during the test period will, if the stations are sufficiently numerous and are satisfactorily distributed, account for rleative mileage of the different types of vehicles on the highways in question. The greater the mileage during the test period of any vehicle, the greater the likelihood that it will pass a given counting station. If the information needed, as in this case, is relative mileage, counting the relative numbers of the vehicles passing the counting stations will provide it. If what is wanted is the relative numbers of vehicles of different types on the highways at a given moment, the proper test is an actual count of the numbers of each type to be found on selected stretches of highway at that moment. In each case, of course, the results obtained are merely an index of the situation whose accuracy is dependent on the accuracy of the count, the sufficiency in number and in location of the counting stations, the degree to which conditions at the test period are representative of conditions at other times, and other such factors.

vehicles, since such differentiation would open the path to serious political dangers, and in any case would probably be held unconstitutional in most of the States.

A more desirable procedure would be, in case it were found that the contributions of urban vehicle owners were more than proportionate to their use of rural highways, to refund to the city treasuries from the motor vehicle tax revenues sufficient to equalize the ratios of contribution to the ratios of use. On the other hand, if it should be disclosed that urban vehicles are contributing less than in proportion to their use of the rural highways, which in the light of the scanty evidence available scarcely seems likely, adjustment could be made by contributing more generously out of the State revenues to the cost of rural local or secondary highways used mainly for local rural traffic. In all cases account should be taken of the relative contributions of urban and rural areas to the State and county highway funds by means of property and other taxes as well as by means of motor-vehicle license and gasoline taxes. As a rule, road district taxes and special assessments are in rural areas now used only in the financing of local roads which serve primarily local needs and are not used to any appreciable extent by urban vehicles. But where primary highways are financed by these methods credit should be given to the rural areas for their contributions in this form.

### STATE AND COUNTY GRANTS TO CITIES FOR HIGHWAY PURPOSES

In a number of States grants are made by the State out of its highway funds to the cities for use in financing city streets. The treatment in this respect of large cities is often different from that accorded to small towns, and we will deal first with the cases in which cities over 30,000 in population receive State aid for street purposes from the State, either immediately or intermediately through the counties, and either in the form of appropriated grants or by permitting the cities to share in the motor vehicle tax revenues. Most of these instances are of very recent origin and are the result of pressure from the cities for a share in the motor-vehicle tax revenues, but some of them are of long standing. While the list which follows may not be quite complete, it is believed to include all of the more important instances.

Alabama: 20 per cent of the net receipts from State motor-vehicle licenses collected within municipal limits is returned to the municipality where collected.

California: 50 per cent of the receipts from State motor-vehicle and gasoline taxes is returned to the counties. The city of San Francisco, which is also the county of San Francisco, and apparently also the city of Los Angeles, through the county of Los Angeles, share in the State motor-vehicle revenues through the apportionment to the counties.

Colorado: 50 per cent of the motor vehicle license fees and the gasoline tax receipts collected within each county is returned to the county. Denver city and Denver County are coterminous, and Denver city therefore receives 50 per cent of the State motor-vehicle tax revenues collected within its limits.

Maryland: The city of Baltimore, which is a seperate unit in the organization of the State, receives from the State 20 per cent of the State motor-vehicle revenues.

New York: New York City, as a unit in the county organization of the State, receives 25 per cent of the State motor vehicle registration fees collected within its limits.

Ohio: Cities receive 50 per cent of the State motor-vehicle license fees collected within their limits and 30 per cent of the gasoline tax receipts.

Oklahoma: 90 per cent of the State motor license fee receipts is returned to the county where collected, and 25 per cent of the county's share is returned to the cities and towns within the county.

Pennsylvania: Philadelphia, which is coterminous with Philadelphia County, received in 1925 a grant of $250,000 from the State motor license fee receipts.

Wisconsin: The State makes grants to cities out of its highway fund as follows: (*a*) City streets connecting portions of the State highway system, $300 to $500 per mile, depending upon the classification of the streets; (*b*) other city streets, cities with population over 10,000, $100 to $200 per mile of street, the amount per mile increasing with the population.

### OTHER FORMS OF AID TO CITIES

In a few instances State aid is given to large cities for highway purposes in other ways than by grants or by refunds of a fraction of the motor vehicle tax receipts. In Alabama, Iowa, and Kansas the State shares in the cost of construction of highways within city limits which connect the street system with the State highway system. In Washington the State pays the cost of maintenance of State highways within city limits. In other States, as, for instance, California for one State route passing through Los Angeles, and Louisiana for two State routes passing through New Orleans, the State in exceptional cases contributes to the cost of specified State routes passing through or on the outskirts of large cities. As a general rule, subject only to occasional exceptions under special circumstances, all other States require the larger cities and towns to finance from their own municipal funds the pavements which are connecting links in the State highway systems.

In general, also, the counties make no contribution out of county tax revenues to the financing of the streets of large cities, though the situation is complicated in a number of instances by the merging of the county with the municipal governmental organization. Three exceptions to this general rule have been found, however. In Arkansas and Florida the counties turn over to the cities within their limits for street use part of the proceeds of the county road taxes. In the State of Washington 50 per cent of the cost of arterial streets in excess of assessments against neighboring property is borne by the counties or the districts with which such streets connect. Nebraska presents an exceptional instance of the reverse character. Not only do the State and the counties make no contribution to the financing of the streets of the larger towns, but the cities of Omaha and Lincoln are required to contribute out of city funds 50 per cent of the cost of construction of outlet highways outside their limits but adjacent thereto.

These various grants from State and county funds in aid of urban highway finance follow no uniform rule, and there is no evidence which indicates that the basis of apportionment of the State and county funds between urban and rural purposes has in any instance been determined by consideration of the respective ratios of urban and rural use of the highways and urban and rural contributions through taxation to their support. In a number of the instances cited cities share in the State motor vehicle tax revenues only because of the accidental fact that the municipal and county organizations have been merged or are coterminous. These grants are not very important even in the aggregate, an examination of the detailed evidence indicating that they did not exceed $20,000,000

(Continued on page 240.)

# COMMON-CARRIER TRUCK FEES AND TAXES

Reported by HENRY R. TRUMBOWER, Economist, United States Bureau of Public Roads

THE special character of business carried on by common-carrier motor trucks is recognized by a great many of the States in the levying of a special license or registration fee upon vehicles engaged in this kind of operation which is considerably higher than the fees charged for the operation of a motor truck by a private operator. At the close of 1925 there were 25 States which charged these extra fees.[1] Certain of these States have also in effect laws which provide that such common-carrier motor trucks may not be operated over regular routes and according to definite schedules unless certificates of public convenience and necessity are first obtained from the public service commission or other regulating agency of the State.

There are also several States which place common-carrier motor trucks under the jurisdiction of their respective public service commissions which do not require a higher license fee of the common-carrier vehicles than they do of trucks operated as private carriers. The States which have in effect public convenience and necessity laws applicable to common-carrier trucks are 27 in number.[2] The States of Arkansas, Idaho, and Mississippi charge special license fees for common-carrier motor trucks, but do not regulate the movement and operation of such vehicles by requiring their operators to obtain certificates of public convenience and necessity before such operations can be engaged in by their owners.

In order to make a comparison of the license fees charged in the 25 States in which special fees are charged the license-fee schedule of each State has been applied to a uniform type of truck conforming to specifications as follows: Pneumatic tires; weight, 7,000 pounds; capacity, 6,000 pounds; 30 horsepower; value, $4,500; annual gross receipts, $12,000; total annual mileage, 20,000 miles; total tire width, 20 inches; total annual gasoline consumption, 4,000 gallons. Certain of these specifications or a combination of them are necessary in order to arrive at the amount of license fees and taxes which carriers of this type have to pay in all States. In Table 1 the license fees which a common-carrier motor truck of these given specifications has to pay are shown in relation to the license fees which in the same States the same type of truck would have to pay if not operated as a common carrier. The difference between the two rates, for lack of a better name, is called the franchise fee.

If one such truck were registered and licensed as a common carrier in each of the 25 States the average fee would be $276.34; if the same truck was licensed as a private carrier the average fee would be only $64.03. The fact that the truck is operated as a common carrier under the assumptions made herein necessitates the payment of $212.31 on the average over and above the fees charged the ordinary truck operated by a business or manufacturing concern but not engaged as a common carrier. This difference may be regarded as a payment for a certain privilege. In all of the 25 States except Arkansas, Idaho, and Mississippi the owners of the trucks operated as common carriers must first obtain permits or certificates of public convenience and necessity, which protect the holders from unwarranted and uneconomical competition on the part of other truck operators who may desire to run their trucks over the same route or routes. On the other hand, the holder of such a certificate finds that his service and rates are regulated by the State in the same manner as rail carriers and public utility corporations.

TABLE 1.—*License fees charged by 25 States for a 3-ton truck of the given specifications when used as a common carrier and a private carrier*

| State | License fee as a common carrier | License fee as a private carrier | Franchise fee |
|---|---|---|---|
| Arizona | $120.00 | $15.00 | $105.00 |
| Arkansas | 187.50 | 125.00 | 62.50 |
| California | 498.00 | 18.00 | 480.00 |
| Idaho | 600.00 | 65.00 | 535.00 |
| Illinois | 205.00 | 75.00 | 130.00 |
| Iowa | 425.00 | 100.00 | 325.00 |
| Kansas | 185.00 | 45.00 | 140.00 |
| Maryland | 433.33 | 9.60 | 423.73 |
| Michigan | 157.50 | 87.50 | 70.00 |
| Minnesota | 450.00 | 108.00 | 342.00 |
| Mississippi | 123.75 | 82.50 | 41.25 |
| Montana | 47.50 | 37.50 | 10.00 |
| Nevada | 480.00 | 39.00 | 441.00 |
| New Mexico | 70.00 | 30.00 | 40.00 |
| North Carolina | 720.00 | 200.00 | 520.00 |
| North Dakota | 132.00 | 82.00 | 50.00 |
| Ohio | 140.00 | 70.00 | 70.00 |
| Oklahoma | 100.00 | 60.00 | 40.00 |
| Oregon | 45.00 | 35.00 | 10.00 |
| South Carolina | 150.00 | 60.00 | 90.00 |
| South Dakota | 360.00 | 75.00 | 285.00 |
| Utah | 400.00 | 40.00 | 360.00 |
| Virginia | 520.00 | 60.00 | 460.00 |
| Washington | 209.00 | 25.50 | 183.50 |
| West Virginia | 150.00 | 56.25 | 93.75 |
| Average | 276.34 | 64.03 | 212.31 |

### THE BASIS OF THE EXTRA CHARGE

From the discussions in legislative assemblies when proposals are made to charge higher fees for common-carrier motor trucks and passenger vehicles it appears that the theory behind this additional charge is not so much that an extra payment should be made for the so-called "monopoly privilege," but that extra charges should be made in order that the State and the public may receive extra compensation for the use of the highway. In most of these license-fee schedules there is found a mixture of the "privilege" theory and the "use of the highway" theory, with the latter theory predominating. There are two aspects of this theory, one of which may be called the compensatory aspect and the other the business aspect, which are closely allied.

The State takes the position, in the first place, that in licensing two trucks of similar size and capacity the one engaged as a common carrier should be obliged to pay a higher license fee than the private carrier because in all probability the mileage of the common-carrier vehicle will be much the greater and that the operation is in most cases a steady one every day of the year, irrespective of road and weather conditions. Such operation is calculated to result in greater wear and tear on the road, according to the view held by the

[1] Arizona, Arkansas, California, Idaho, Illinois, Iowa, Kansas, Maryland, Michigan, Minnesota, Mississippi, Montana, Nevada, New Mexico, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, South Carolina, South Dakota, Utah, Virginia, Washington, and West Virginia.

[2] Arizona, California, Colorado, Illinois, Indiana, Iowa, Kansas, Maryland, Michigan, Minnesota, Montana, Nebraska, Nevada, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Utah, Virginia, Vermont, Washington, West Virginia, and Wyoming.

legislators, involving higher maintenance costs and requiring in some cases a more costly road construction in the first place. The higher fee is intended to cover items of this nature.

The business aspect is quite different. The fact that an individual or a company puts upon the public highway a motor truck not engaged in transporting the products or goods of the owner but in carrying goods offered for transportation by other business men or the public puts the owner and the truck in a special class; the public highway in such a case becomes an important element in a new business enterprise, and profits are sought by motor-truck operators in this sort of enterprise. There arises, therefore, in the minds of legislators the feeling that where operators use the highways as a part of their business enterprises an extra fee should be charged. Furthermore, in considering this type of highway transportation from the business point of view the legislator is urged, at least by those interested in rail transportation, that these extra license fees and taxes levied against common-carrier motor vehicles should be fixed at a point which will equalize competitive costs.

The common-carrier license fees differ widely in the several States, as will be noted, and the differences between the common-carrier fees and the private-carrier fees are still more pronounced. The common-carrier fees range from $45 in Oregon to $720 in North Carolina, and between these limits the various fees are classified as shown in Table 2. Slightly over half of the States, as will be seen from this tabulation, charge less than $200 as a license fee for this type of carrier; approximately a fourth charge between $400 and $500. The two which in the table are shown to receive more than $600 are States which charge certain percentages of the gross earnings in lieu of a regular license fee. The $12,000 gross earnings assumed in this hypothetical case bring the taxes up to these high amounts. The earnings assumed, however, averaging $40 a day, are believed to be reasonable and normal for this size of truck.

TABLE 2.—*Classification of common-carrier motor-truck license fees in 25 States*

| License fee | Number of States | Per cent | License fee | Number of States | Per cent |
|---|---|---|---|---|---|
| Less than $100 | 4 | 16 | $500 to $599 | 1 | 4 |
| $100 to $199 | 9 | 36 | $600 to $699 | 1 | 4 |
| $200 to $299 | 2 | 8 | $700 to $799 | 1 | 4 |
| $300 to $399 | 1 | 4 | | | |
| $400 to $499 | 6 | 24 | Total | 25 | 100 |

**WIDE DIFFERENCE IN FRANCHISE FEES**

The franchise fees vary from $10 in Montana and Oregon to $535 in Idaho, their classification between these limits being as set forth in Table 3.

TABLE 3.—*Classification of franchise fees for common-carrier motor trucks in 25 States*

| Franchise fees | Number of States | Per cent | Franchise fees | Number of States | Per cent |
|---|---|---|---|---|---|
| Less than $100 | 11 | 44 | $400 to $499 | 4 | 16 |
| $100 to $199 | 4 | 16 | $500 to $599 | 2 | 8 |
| $200 to $299 | 1 | 4 | | | |
| $300 to $399 | 3 | 12 | Total | 25 | 100 |

It is significant that the average of the franchise fees is over three times as great as the average fee paid by this type of truck not registered as a common carrier. Although in 44 per cent of the States it is less than $100, the high additional fees in a number of the other States bring the average up to over $200.

In order to determine to what extent there is a trend towards uniformity and what motives predominate in drawing up license-fee schedules, it is of interest to analyze and classify the various methods followed in arriving at the exact fees to be charged. Table 4 has, therefore, been prepared to show the various bases used in determining the license fees for common-carrier and privately operated trucks in the 25 States, and Table 5 to summarize and classify the same information.

TABLE 4.—*Basis of license fees for common-carrier and privately owned trucks in 25 States*

| State | Basis of private truck license | Basis of common-carrier truck license |
|---|---|---|
| Arizona | Capacity | Capacity-mile. |
| Arkansas | do | Capacity. |
| California | Flat rate plus weight | Flat rate plus weight plus gross receipts. |
| Idaho | Capacity | Gross receipts. |
| Illinois | Gross weight | Gross weight. |
| Iowa | Capacity | Capacity-mile. |
| Kansas | do | Capacity. |
| Maryland | Horsepower | Capacity-mile. |
| Michigan | Weight | Weight. |
| Minnesota | Value | Value. |
| Mississippi | Capacity | Capacity. |
| Montana | do | Flat rate plus capacity. |
| Nevada | Gross weight | Gross receipts. |
| New Mexico | Flat rate plus capacity | Flat rate plus capacity. |
| North Carolina | Capacity | Gross receipts. |
| North Dakota | Value plus weight plus horsepower plus capacity. | Value plus weight plus horsepower plus capacity. |
| Ohio | Weight | Capacity. |
| Oklahoma | Capacity | Mileage plus capacity. |
| Oregon | Tire width | Tire width. |
| South Carolina | Capacity | Gross weight plus capacity-mile. |
| South Dakota | do | Gross receipts. |
| Utah | do | Capacity-mile. |
| Virginia | do | Gross weight-mile. |
| Washington | Weight | Gross weight plus gross receipts. |
| West Virginia | Capacity | Capacity-mile. |

TABLE 5.—*Classification of license fee basis for common-carrier and privately owned trucks in 25 States*

| Basis | Private trucks, number of States | Common-carrier trucks, number of States |
|---|---|---|
| Capacity | 14 | 4 |
| Weight | 3 | 1 |
| Gross weight | 2 | 1 |
| Flat rate plus weight | 1 | |
| Horsepower | 1 | |
| Value | 1 | 1 |
| Flat rate plus capacity | 1 | 2 |
| Value plus weight plus horsepower plus capacity | 1 | 1 |
| Tire width | 1 | 1 |
| Gross receipts | | 4 |
| Capacity-mile | | 5 |
| Flat rate plus weight plus gross receipts | | 1 |
| Mileage plus capacity | | 1 |
| Gross weight plus capacity-mile | | 1 |
| Gross weight-mile | | 1 |
| Gross weight plus gross receipts | | 1 |
| Total | 25 | 25 |

In 22 of the 25 States listed weight in some form or other constitutes the chief basis for determining the amount of the ordinary license fees; in 14 States the rated carrying capacity of the truck is used as a basis; in 3 the unladen weight of the truck; in 2 the gross

weight of the truck; and in the others there are combinations of weight or capacity with a flat charge and with horsepower. Only 3 States use as a basis some factor other than weight (or capacity). One of these uses horsepower, another the value of the truck, and the third tire width.

### HIGHWAY USE A POPULAR BASIS FOR COMMON-CARRIER FEES

When we come to a study of the basis used in determining the license fees for common-carrier motor trucks it is seen that the use which the truck makes of the highway becomes one of the most important considerations. The license fees charged for the private trucks are in no way affected by the extent to which the highway is used. A truck of a given size or capacity pays in the several States the same respective license fees whether it is operated during a year's period 100 miles over the public highways or 20,000 miles, so long as it is used privately. But in the common-carrier rates, on the other hand, there is a decided shift in the basis of the fees, tending from the fixed fee regardless of the use made of the highways or the amount of business done to a fee which reflects to a large degree the amount of operation over the highway and the amount of business transacted. Fourteen of the 25 States have introduced this factor in some form, measured variously by gross receipts, mileage, capacity-mile, or weight-mile. The gasoline tax is, of course, another way in which recognition is given to this factor of highway use; and this tax is paid by the privately owned trucks as well as by the common carriers. But, presumably, it is paid in greater amount by the latter because of their more extensive operation.

In the following analysis the basis of the common-carrier fees in these 25 States are examined in detail in order to develop more clearly the principles followed in the taxation of vehicles of the special class.

*Fees based on truck capacity.*—Of the four States, Arkansas, Kansas, Mississippi, and Ohio, in which license fees for common carriers are based on the capacity of the vehicle, two, Arkansas and Mississippi, arbitrarily add 50 per cent to the rates charged for private trucks. Kansas charges the common-carrier truck the regular license fee for trucks which is based on capacity, and then adds to this a flat fee varying with the capacity of the truck. In Ohio the private truck is charged a fee the amount of which depends upon its weight. The common-carrier truck, on the other hand, pays a fee which is based on its carrying capacity. Common-carrier trucks that are not operated over regular routes and between fixed termini pay from 30 to 40 per cent less than trucks that are scheduled to operate over regular routes. This differential is explainable in part upon the assumption that the truck that does not operate over a regular route will not make as much use of the highways as a regular truck, and in part by reason of the special privileges granted to the truck engaged in regular service over a definite route.

*Fees based on truck weight.*—Michigan is the only State in which the fee depends solely upon the weight of the truck. The fees for private trucks are determined upon the same basis, but in the case of the common carrier an extra charge for each 100 pounds is added to the regular license fees.

*Fees based on gross weight of truck.*—In Illinois private trucks are classified according to gross weight (weight of the truck plus its rated capacity) and the fees are fixed accordingly. A common-carrier truck has to pay, in addition to these regular registration fees, a special fee of $1 per 100 pounds gross weight.

*Fees based on the value of the truck.*—In only one State, Minnesota, is value made the basis upon which license fees are charged for all types of motor vehicles, passenger cars and trucks alike. The rate for private trucks is 2.4 per cent of their value (the value being the manufacturer's price less a fixed rate of depreciation per year), whereas a truck engaged in the general transportation business over a regular route is obliged to pay a license fee of 10 per cent of its value.

*Fees based on flat rate plus capacity.*—Montana varies its schedule of license fees for private trucks according to capacity. The same rates are charged for common carriers, with an additional fee amounting to not more than $10. In New Mexico, the only other State which uses this basis, a flat sum is charged, and to this is added a certain rate per 100 pounds of carrying capacity. In the case of the common-carrier truck both the flat rate and the rate per 100 pounds capacity are increased by about 50 per cent.

*Fees based on value plus weight plus horsepower plus capacity.*—North Dakota employs the four factors of value, weight, horsepower, and capacity in arriving at the license fee for a private truck. For a common carrier the capacity rates are practically doubled, and in addition a special fee, based upon capacity, must be paid to the railroad commission, the State agency which has jurisdiction and control over common-carrier motor truck operations.

*Fees based on tire width.*—Oregon bases its license fees for private motor trucks upon total tire width. Trucks which engage in common-carrier service pay 50 cents per inch of tire width more than the other trucks, which is an increase of about 25 per cent.

### STATES IN WHICH HIGHWAY USE IS THE BASIS

*Fees based on gross receipts.*—Four States use the gross receipts from the operation as the basis for determining the amount of license fees or taxes which a common-carrier motor truck should pay. It is held that the amount of receipts is a reasonably fair index of the amount of business done, and in turn of the use made of the highways by the vehicle producing the earnings. The four States following this method are Idaho, Nevada, North Carolina, and South Dakota, and the charges range from 3 per cent to 6 per cent of the gross receipts. South Dakota collects 3 per cent, Nevada 4 per cent, Idaho 5 per cent, and North Carolina 6 per cent. In some cases the payments are made monthly and in other cases quarterly.

*Fees based on the capacity-mile.*—In charging license fees which are based upon the number of miles operated multiplied by the number of tons of carrying capacity, an attempt is made to make the contribution of common-carrier motor trucks depend directly upon the use which is made of the highways. Tonnage and mileage are the two best indices. Actual tonnage would be still better, but in order that the law may be practically administered it is necessary to use capacity instead. In most cases the collection is made in advance at the time the license is issued. The carrying capacity of the truck and the mileage over which it is proposed to operate it are indicated on the application, and from these data the capacity-mileage for the year is computed.

Five States have adopted this basis. The fees range from one-sixth to two-thirds of a cent per ton-mile. Arizona charges one-fifth cent, Iowa one-half cent per ton-mile. Maryland grades her ton-mile rate from one-sixth to one-third and one-half cent per ton-mile, depending upon the weight of the truck and the type of tire equipment. Utah instead of classifying the truck classifies her highways. Common-carrier trucks operating over hard-surfaced roads pay a rate of two-third of a cent per ton-mile, while those which operate over roads that are not hard surfaced pay at the rate of only one-fourth cent per ton-mile. This classification involves two well-recognized principles of highway finance. The first, which is axiomatic, is that the more a State spends on highway improvement the more revenue it must have to meet such expenditures; and the second is that the greater the degree of highway improvement the more will motor-vehicle operators be able to afford in the way of license fees or taxes on account of the reduction in the costs of operating the motor vehicle. In this case the license fee charged for operating over hard surfaced roads is more than double that charged for operating over other types of roads, and there is slight doubt that the operators gladly pay the additional fees in order to have the benefit of the better roads. West Virginia charges a rate ranging from one-fourth to one-third cent per ton-mile, depending upon the weight of the vehicle used.

*Fees based on flat rate plus weight plus gross receipts.*—California is the only State in this group. The private carrier is charged a fee based on the weight of the truck plus a flat fee of $3. Common carriers have to pay this same fee plus 4 per cent of the gross receipts.

*Fees based on mileage plus capacity.*—In Oklahoma the private motor truck is charged a license fee depending on the capacity of the truck. A common carrier pays this same fee, and in addition is obliged to pay a fee of one-fifth cent per mile on the distance traveled.

*Fees based on gross weight-mile.*—The private motor-truck fee in Virginia is based on capacity. The fee for a common carrier, on the other hand, is determined by multiplying the gross weight of the vehicle by the number of miles traveled times one-fifth cent for the smaller trucks, two-fifths cent for larger trucks, and three-fifths cent for the trucks of the heaviest class.

*Fees based on gross weight plus gross receipts.*—Washington is the only State using this method. Private trucks pay fees which are based on weight. Common-carrier trucks are charged on the basis of gross weight, and in addition an amount not to exceed 1 per cent of the gross receipts. The part of the fee which is based on the gross receipts is credited to the funds of the public service commission and is intended to cover the costs incurred by that body in the regulation and supervision of common-carrier motor vehicles.

#### GASOLINE TAXES OF THE 25 STATES

These license fees are supplemented in every one o the States under consideration, except Illinois, by gasoline taxes which vary from 1 to 5 cents per gallon. It is assumed that the truck which has been used in this study for comparative purposes will consume approximately 4,000 gallons in operating 20,000 miles, and on this basis the gasoline taxes which would have to be paid in the several States, together with the license fees and the total license fees and gasoline taxes, are set forth in Table 6.

TABLE 6.—*Common-carrier motor-truck license fees and gasoline taxes of 25 States*

| State | License fee | Gasoline tax | | Total license fee and gasoline tax |
|---|---|---|---|---|
| | | Rate per gallon in cents | Amount | |
| Arizona | $120.00 | 3 | $120.00 | $240.00 |
| Arkansas | 187.50 | 4 | 160.00 | 347.50 |
| California | 498.00 | 2 | 80.00 | 578.00 |
| Idaho | 600.00 | 2 | 80.00 | 680.00 |
| Illinois | 205.00 | ---------- | ---------- | 205.00 |
| Iowa | 425.00 | 2 | 80.00 | 505.00 |
| Kansas | 185.00 | 2 | 80.00 | 265.00 |
| Maryland | 433.33 | 2 | 80.00 | 513.33 |
| Michigan | 157.50 | 2 | 80.00 | 237.50 |
| Minnesota | 450.00 | 2 | ·80.00 | 530.00 |
| Mississippi | 123.75 | 3 | 120.00 | 243.75 |
| Montana | 47.50 | 2 | 80.00 | 127.50 |
| Nevada | 480.00 | 4 | 160.00 | 640.00 |
| New Mexico | 70.00 | 3 | 120.00 | 190.00 |
| North Carolina | 720.00 | 4 | 160.00 | 880.00 |
| North Dakota | 132.00 | 1 | 40.00 | 172.00 |
| Ohio | 140.00 | 2 | 80.00 | 220.00 |
| Oklahoma | 100.00 | 3 | 120.00 | 220.00 |
| Oregon | 45.00 | 3 | 120.00 | 165.00 |
| South Carolina | 150.00 | 5 | 200.00 | 350.00 |
| South Dakota | 360.00 | 3 | 120.00 | 480.00 |
| Utah | 400.00 | 3½ | 140.00 | 540.00 |
| Virginia | 520.00 | 3 | 120.00 | 640.00 |
| Washington | 209.00 | 2 | 80.00 | 289.00 |
| West Virginia | 150.00 | 3½ | 140.00 | 290.00 |
| Average | 276.34 | ---------- | 105.60 | 381.94 |

The average license fee paid in the 25 States by a common-carrier truck of the assumed specifications is $276.34, the average gasoline tax $105.60, making a total of $381.94 per truck. The total payments range from $127.50, the charge made by Montana, to $880, by North Carolina. In the light of the average the gasoline tax is the smaller part of the total payment, averaging 27 per cent of the total. There are 5 States, however, where the gasoline tax exceeds the license fee; these are Montana, New Mexico, Oklahoma, Oregon, and South Carolina.

In addition to these two types of fees and taxes the common-carrier motor trucks are subject in most States to the general property tax. The amount of that payment depends altogether on the assessed valuation and the tax rate. It should be noted, however, that seven of the States dealt with in this article have relieved the common-carrier motor truck by specific statutory exemptions from the payment of property taxes. These States are Idaho, Iowa, Michigan, Minnesota, North Dakota, Oklahoma, and Oregon. In a number of the States, on the other hand, cities and incorporated towns are permitted to charge special license fees for trucks engaged in common-carrier service and make a practice of doing so. The available data are not sufficient to determine closely what such municipal license fees and general property taxes amount to in the several States, but it is believed that they amount to a fairly substantial yearly payment on the average.

#### INTERSTATE OPERATION DOUBLY TAXED

Where interstate operations are involved common-carrier motor trucks operating over regular routes between two States are required to take out licenses in each of the States. If the license fees in each of the States involved are measured by a mileage or gross-earnings factor the total registration fee is no greater for the interstate than for intrastate operation. But

if the interstate operation occurs between two States each of which has in effect license-fee schedules based upon capacity or weight it is necessary to pay the full license fee in each State. For example, a common-carrier motor truck operating between a point in Minnesota and a point in North Dakota would have to pay the $450 fee for a 3-ton truck with the given specifications in Minnesota, and $132 in North Dakota in addition to the gasoline tax. In all of the States except those which base their fees on ton-mileage or gross receipts it is more expensive to operate common-carrier motor trucks in interstate than in intrastate commerce.

These average license fees and gasoline taxes, which for a common-carrier truck amount to $381.94 are approximately 3.2 per cent of the assumed annual gross receipts of $12,000. How nearly this ratio actually holds true can not be definitely determined on account of the lack of operating and financial reports. According to the assumptions that have been made this type of motor truck under consideration would have to pay in Maryland a license fee and gasoline taxes which would amount to 4.3 per cent of its annual earnings. In the same State eight motor-truck operators reported in 1924 that their taxes and license-fee payments amounted to 5.7 per cent of their gross receipts. In this report the personal property taxes were undoubtedly included, but the taxes concealed in their gasoline costs do not appear as a tax item. Accordingly, it appears that at least in this particular case the total tax burden, including personal property taxes, license fees, and gasoline taxes, amounted to a sum in excess of 6 per cent of the gross earnings.

It may be of interest further to compare these tax payments with the tonnage carried in order to determine the amount of the tax burden on the actual service rendered. Table 7, therefore, shows the total of license fees and gasoline taxes for each State reduced to a ton-mile basis, using the assumptions made throughout this article.

TABLE 7.—*Tax-burden per ton-mile*

| State | License fee and gasoline tax per capacity ton-mile | State | License fee and gasoline tax per capacity ton-mile | State | License fee and gasoline tax per capacity ton-mile |
|---|---|---|---|---|---|
| | *Mills* | | *Mills* | | *Mills* |
| Arizona | 4.0 | Minnesota | 8.8 | Oregon | 2.7 |
| Arkansas | 5.8 | Mississippi | 4.0 | South Carolina | 5.8 |
| California | 9.6 | Montana | 2.1 | South Dakota | 8.0 |
| Idaho | 11.3 | Nevada | 10.6 | Utah | 9.0 |
| Illinois | 3.4 | New Mexico | 3.2 | Virginia | 10.6 |
| Iowa | 8.4 | North Carolina | 14.7 | Washington | 4.8 |
| Kansas | 4.4 | North Dakota | 2.9 | West Virginia | 4.8 |
| Maryland | 8.6 | Ohio | 3.6 | | |
| Michigan | 3.9 | Oklahoma | 3.6 | | 6.3 |

The average tax burden of 6.3 mills per capacity ton-mile is based on the assumption of a full capacity load for every mile operated. For a 50 per cent load factor these fees and taxes would amount to 12.6 mills per ton-mile, and for a 75 per cent load factor they would be 9.4 mills per ton-mile. As investigations have shown that the actual load factor commonly ranges between 50 and 75 per cent, it may be fairly assumed that the latter averages are nearer to the fact than the lower average shown in Table 6.

An examination of license fees and an investigation of tax burdens which the several States are placing upon motor trucks engaged in common-carrier service tends to show that in the past few years many of the States have passed laws requiring the common-carrier truck to pay license fees which on the average are approximately four times the fees charged for privately operated trucks. More and more States have followed this policy of exacting higher fees from the common-carrier vehicle. There appears to be a lack of uniformity as to measures employed to determine the amount of the fee, but there is evidence of a tendency to use means which reflect the use made of the highways furnished for this business by the public and which furnish an index of the operator's ability to pay in that he is supposed to be able to pay a higher fee if his gross earnings are large than if they are small.

## URBAN ASPECTS OF HIGHWAY FINANCE

(Continued from page 235)

in 1923 for all cities in the United States having a population of 30,000 or over.

Small towns, and especially those under 2,500 in population, receive more generous treatment. It is the general rule or the frequent practice in a majority of the States for the State itself to construct or to provide funds for the construction of standard sections of State highways passing through towns not exceeding a specified population; in some cases maintenance also is provided by the State. This is a desirable practice, if for no other reason than to provide a safeguard against serious impairment of the efficiency of State highway systems through the persistence of unpaved or unsatisfactorily maintained sections within the limits of small towns. In a few States, especially in New England, small towns receive aid from the State in financing their general street program, whereas larger cities receive no such aid. This may perhaps be justified on the ground that for very small towns the town limits are not to any appreciable extent traffic boundaries, and common financing with the surrounding rural highways is logical. In States in which the county is an important political unit it would be more desirable that any aid given to small towns for their general street program should be given by the county rather than by the State. Such streets, like local rural roads, render little service to the dwellers in large cities, and they should not be made, through their contributions to the State tax revenues, to contribute to their support.

## LANDSLIDES TO BE STUDIED

The United States Bureau of Public Roads has assigned Dr. George E. Ladd, geologist, to a study of the problems involved in landslides in West Virginia and Ohio, with particular reference to the effect of slides on road construction.

A preliminary survey has been completed in the two States. For the future it is planned to make a field study of the geological and topographic conditions involved, and a detailed study of the different types of slide which are about equally divided between side-hill and fill slides. Possibilities of surface drainage will be investigated and field experiments will be conducted. In addition to the field work, laboratory experiments will be made on average samples of slide material from different localities.

# EFFICIENCY IN CONCRETE ROAD CONSTRUCTION

## A REPORT OF OBSERVATIONS MADE ON GOING PROJECTS BY THE DIVISION OF CONTROL, BUREAU OF PUBLIC ROADS

Reported by J. L. HARRISON, Highway Engineer

### PART III.—THE EFFICIENCY OF EQUIPMENT

IN THE previous article the fact was brought out that the cost of hauling material increases rapidly with the distance it is hauled. This in turn increases the cost of the paving. It is, therefore, advisable, other things being equal, to keep the haul from the material yards to the mixer as low as possible. But even when appropriate sites for material yards are so favorably located as to make possible a series of short hauls for the entire project, the advantage of these natural conditions may be largely lost to the contractor unless his material-handling plant is so constructed that it can be moved from one site to another expeditiously and at small expense.

If the element of mobility is ignored, the problem of moving from one material-handling yard to the next is a serious one, not so much because of the increase in the direct cost as because of the time involved. When operations must be closed down even for a day or two some of the men are almost certain to leave. Then when operations are resumed men who are not familiar with the work must be employed and trained before the organization will run smoothly. The result is a series of expensive intangible losses very hard to calculate. To avoid such losses every unit in the material-handling plant should be so designed that it can be moved between quitting time at night and the resumption of work next morning.

The probability that the crew will be more or less demoralized by closing down the work is so great that contractors often keep their men employed during periods when the material-yard equipment is being moved, even though the work done is valueless from the production standpoint. This practice generates tangible losses equal to the amount paid for the performance of useless work, but these losses are accepted by the contractors as preferable to the intangible losses faced when trained men leave. As such operations may run for two or three days, the importance of the losses incident to any slowness in changing the material-yard set-up and the real value of high mobility are apparent. Rollers, tractors, trucks, etc., are highly mobile. They can be transferred to a new base of operations cheaply and within a short time. Modern mixers, cranes, and other items of heavy equipment have some degree of mobility, but manufacturers could well give more consideration to this feature in design. There is a good deal of complaint among contractors that when such equipment must be moved any considerable distance under its own power there is a tendency for bearings and clutches to overheat, with the result that frequent long stops have to be made to keep them from burning out. This condition can be and should be so fully corrected that mixers and crawler-type cranes can be moved expeditiously and under their own power any reasonable distance, even over unimproved roads. The exact speed which they should be able to maintain is of less importance. Two or three miles an hour would be fast enough. But they should be able to accomplish these trips without the necessity of making long and repeated stops to cool bearings and clutches.

Bins, hoppers, etc., even many of the best of those manufactured for use on concrete paving jobs, seem to have been designed with little thought of portability. They should be built in rigid sections and provided with holes or handles at points which can be reached by the crane, so that by removing a few pins or a few bolts each section can be lifted down and placed on a truck. There is no reason why the steel hoppers used for sand and coarse aggregate should not be so designed that they can be taken down in a few hours, hauled to the new location, and erected in about the same length of time. Detail plans for both erection and dismantling, as well as instructions governing the performance of these operations, should be furnished with all equipment of this kind.

#### THE PROPER USE OF THE STOCK PILE

The most commonly accepted practice in handling concrete aggregates is the use of bins and hoppers. This, however, is not the only method applicable to this work. It may therefore be well to refer again to the fact that present-day manufacturing enterprises—and laying a concrete pavement is typically a manufacturing enterprise—do not depend so largely on the accumulation of heavy stocks of materials as they do on properly adjusted rates of delivery of the necessary materials. The stocks serve merely to absorb temporary excesses in the rate of delivery and are drawn upon only when there is a deficiency in the rate of delivery. If, in laying concrete pavements, the rate of rail delivery could be maintained in exact harmony with the rate of use at the mixer, no material would need to go to the stock piles. But this is, of course, a condition impossible of attainment on a job of any length, since weather conditions and other unpreventable causes hinder the attainment of uniformity in the rate of output, even though the production of the mixer while it is at work be maintained at a uniform rate. In practice, therefore, there are periods when some material must go to the stock piles and others when materials must be withdrawn. The closer the approach to a direct transfer of materials from cars to job the greater, of course, will be the economy of operation. A direct transfer involves handling the materials but once. Passing the materials through the stock piles involves handling them twice, and where the piles become very large a third handling may be necessary. In the latter case, if the plant is being worked to capacity, it may be necessary to do overtime or night work in moving the materials, thus adding to the extra handling still another expense.

On by far the larger number of concrete paving jobs the materials are delivered at the material yards by rail. The handling equipment should, therefore, be so designed that it will unload railroad cars efficiently. But as there are also jobs where the materials are

secured from local quarries, sand pits, gravel beds, etc., the equipment should also be adaptable to such uses as well as to moving stock-piled materials.

There are four general systems of handling materials used in concrete road construction, in which the operations are as follows:

1. Cars to loading bins or stock piles by crane; bins to trucks or industrial railway cars by gravity.
2. Cars to pit by gravity; pit to stock pile by belt conveyor; stock pile to trucks or cars by elevating bucket conveyors, often known as loading machines.
3. Cranes or belt conveyors to stock piles over tunnels; stock piles to cars, occasionally to trucks, by gravity.
4. Cars to wagons or trucks by hand shoveling; wagons or trucks to job where materials are piled along subgrade; piles to mixer in wheelbarrows.

Of course there are various modifications of all of these methods, and occasionally a new idea is encountered. In general, however, the new methods fail to produce the desired results and are soon abandoned; and much the same may be said of systems 3 and 4, as described above. The latter of these was at one time the all but universal practice; it is now almost entirely out of use. Hand methods are seldom advantageous, even when labor is cheap, for probably the most speculative element in any enterprise of this sort is the output which can be obtained from the labor employed. To reduce the amount of labor required, and particularly to introduce elements which tend to control the amount of work done per man per day, reduces the importance of the speculation involved. The inaccuracy with which the batch is measured has also served to hasten the abandonment of this system of handling materials.

Somewhat the same conditions have all but forced the loading tunnel out of existence. At best the batch is poorly measured by this system; and all things considered, though on the face it is cheap, it has never been very satisfactory.

### THE MODERN HANDLING SYSTEMS

Two really modern systems remain. Both work well and can be successfully operated. The scheme of passing material to pits by gravity, to stock piles by belt conveyer, and through loading machines to the trucks is probably somewhat more mobile. It has the disadvantage, however, of generally using four machines to do the work of the crane and the bins, and as a result the number of men required for successful operation is larger. Some advantage accrues to this system from the fact that where the sand is obtained from one point and the coarse aggregate from another the equipment can be readily divided. The percentage of jobs where this condition prevails, however, is small, and as the pay roll is relatively large it does not now, in spite of the high mobility of the machines involved, seem likely to displace the more general method of handling aggregate, the crane and loading bin.

In the performance of any operation efficiency is attained only when the end is accomplished with the least possible work and when the work that is done is done expeditiously and accurately. Judged by this standard the crane and the loading bin have shown their advantage. In a system involving the constant, steady delivery of material the crane has proved to be a dependable piece of equipment. The standard set-up is simple. The hoppers are set at such a distance from the track that the crane, which should be of the crawler type with a ¾-yard bucket, can work freely between the hoppers and the cars. The distance between stock piles should be such that two cars, one of sand and one of gravel, may be reached. The crane will then unload either into the hoppers or onto the stock piles, this being governed by the number of cars to be handled and the requirements of the mixer.

A good ¾-cubic yard crane in the hands of a skillful operator will move a bucket every half minute from a freight car into the hoppers, and will operate at a slightly higher rate from the stock piles into the hoppers, as indicated by the actual stop-watch readings presented in Table 1. When handling sand the loads will average close to the rated capacity except in very dry sand, which will run out badly if the bucket does not close tight. When handling crushed stone or gravel the loads will average about 0.6 cubic yard. The average load obtained while working from a freight car is less, about 0.6 cubic yard for sand and seldom an average over 0.5 cubic yard for stone. This difference is due principally to the difficulty of getting a full bucket in a nearly empty car. A good operator, however, can take a cubic yard of gravel or stone out of a freight car every minute, and a little more than that amount of sand. With good operation, therefore, the output should be about 60 cubic yards per hour; but the daily rate will seldom reach the hourly rate multiplied by the number of hours. One reason is the delay caused by shifting cars. Another is the fact that if a car of sand and a car of stone are being unloaded into the hoppers it is obvious that the car of stone will be emptied first. If the cars have not been spotted in the proper order it will then be necessary either to get stone from the stock pile until the sand car is emptied or else to empty the sand car onto the stock pile before new cars are brought up. Of course it is desirable to have the cars spotted by the railroad so that as a general practice the string waiting to be unloaded is made up alternately of two cars of gravel or stone and one of sand, but it is not always possible to get train crews to exercise this care in setting off and arranging cars.

TABLE 1.—*Stop-watch readings of time required to handle material by crane from stock piles and cars to batcher plants*

| Time required per load from stock pile to batcher plant | | | | Time required per load from cars to batcher plant | | | |
|---|---|---|---|---|---|---|---|
| Load No. | Time | Load No. | Time | Load No. | Time | Load No. | Time |
| | *Seconds* | | *Seconds* | | *Seconds* | | *Seconds* |
| 1 | 20 | 15 | 26 | 1 | 27 | 17 | 25 |
| 2 | 20 | 16 | 37 | 2 | 29 | 18 | 28 |
| 3 | 20 | 17 | 20 | 3 | 28 | 19 | 30 |
| 4 | 45 | 18 | 23 | 4 | 29 | 20 | 28 |
| 5 | 28 | 19 | 19 | 5 | 28 | 21 | 30 |
| 6 | 23 | 20 | 25 | 6 | 34 | 22 | 40 |
| 7 | 29 | 21 | 31 | 7 | 39 | 23 | 30 |
| 8 | 18 | 22 | 25 | 8 | 33 | 24 | 29 |
| 9 | 25 | 23 | 24 | 9 | 28 | 25 | 29 |
| 10 | 36 | 24 | 30 | 10 | 27 | 26 | 26 |
| 11 | 21 | 25 | 33 | 11 | 28 | 27 | 28 |
| 12 | 28 | 26 | 30 | 12 | 26 | 28 | 30 |
| 13 | 23 | 27 | 27 | 13 | 29 | 29 | 29 |
| 14 | 26 | 28 | 30 | 14 | 25 | 30 | 29 |
| | | | | 15 | 34 | 31 | 33 |
| | | | | 16 | 30 | 32 | 32 |
| Average time per load | | | 26.5 | Average time per load | | | 30 |

The capacity of the crane as a tool for unloading cars is of importance only when for some cause too many have been delivered at one time and it is necessary to get them unloaded in order to avoid demurrage. The vitally important question is whether or not the crane can keep up with the demands of the mixer. It

has been stated that the mixer, when working at full efficiency, can turn out 48 batches of concrete an hour. The mix may be as lean as 1:2:4, which requires approximately 10 cubic feet of sand and 20 cubic feet of coarse aggregate per batch. This is a maximum demand of 480 cubic feet, or about 18 cubic yards of sand and 960 cubic feet or about 36 cubic yards of coarse aggregate, a total of slightly over 53 cubic yards an hour. From this it will be clear that the crane is able to keep up with the mixer even when it is working from the cars to the hopper and the mixer is operating at full efficiency, but that it has rather a narrow margin to work on. It is also clear that if manufacturers develop a 6 or 7 bag mixer which can turn out as many batches an hour as the modern 5-bag mixer, a heavier crane with a larger bucket will be needed to keep up with the mixer when it is working at full efficiency.

#### WINTER STOCK PILING EXPENSIVE

In this connection there is some light that can be thrown upon the practice of stock piling aggregate during the winter, which is so often recommended. By the crane and bin method winter stock piling can be done readily enough wherever space is available. The bucket will take either stone or sand out of the freight cars even though it has been somewhat consolidated by freezing, a more common winter condition than many suppose. The difficulty with this system is its cost. Rail delivery in general is so dependable that if shipments at the source of supply are made according to schedule and the mixer is operating with reasonable efficiency upwards of 75 per cent of the aggregate will go from the cars direct to the job. The other 25 per cent or less will go to the stock piles and then to the hoppers. This generates an average handling of materials approximating 125 per cent. But because few jobs maintain full mixer efficiency this, as a rule, is easily within the capacity of the crane. But when materials are stock piled during the winter there is a 100 per cent unloading onto the stock piles, which then become so large that much of the material must be shifted once, sometimes twice, to get it to a point from which it can be placed in the loading hoppers.

Winter stock piling, therefore, not only increases the cost of handling by the amount of the direct cost of unloading, together with such carrying charges as interest, loss of material (and stock-pile losses are considerable), etc., but also increases the subsequent cost of operation by reason of the fact that if production is well maintained the crane can not shift material and at the same time keep the hoppers filled. The result is that overtime operation must be resorted to in order to keep up the supply of material within reach of the hoppers. In view of these costs and the present outstanding dependability of rail delivery, material concessions in the price of aggregate or in the freight rate for winter delivery must be obtained to justify winter stock piling.

The stock piling of aggregate at convenient points along the road, which is sometimes advocated, is also expensive. In the first place, it increases the truck time required to move the material to its place in the road. Thus, assuming the use of single-batch trucks and the most favorable placement of stock piles, the time required per load for the movement of materials to the stock piles may be represented by the formula:

$$T \text{ (time per trip in minutes)} = 8d_1 + 3, \qquad (1)$$

in which $d_1$ is the distance in miles from the unloading point to the stock pile and the constant 3 is the time, in minutes, required for loading (lower in this case than in standard operation because cement is not handled with the aggregate).

For the subsequent delivery of the same materials to the mixer the time will be represented by the standard formula:

$$T = 8d_2 + 4, \qquad (2)$$

in which $d_2$ is the distance from the stock pile to the mixer. The total time required to deliver a batch to the mixer will, therefore, be:

$$T = 8(d_1 + d_2) + 7. \qquad (3)$$

As $(d_1 + d_2)$ is not likely to be less than $d$, the direct-haul distance from the unloading point, and is often greater, the time as determined from equation 3 is not likely to be less than $8d + 7$, whereas the equation for the time required on direct haul from the unloading point to the mixer[1] is

$$T = 8d + 4. \qquad (4)$$

In some instances the opportunity to make fuller use of a limited truck supply, particularly under conditions involving unusually long haul, may be such as to justify stock piling along the road in spite of the extra hauling cost which this analysis shows to be involved, but as a general practice stock piling in this way can not be defended.

In addition to the increased hauling cost this method has the same disadvantages as stock piling at the unloading point—high material losses and high handling costs. Nor can these ordinarily be offset by any gains at other points. It is sometimes claimed that trucks can be loaded more heavily where materials are stock piled, but as they are now badly overloaded when hauling standard batches this argument is hardly to be countenanced.

#### MODERN STEEL BINS PREFERRED TO HOMEMADE EQUIPMENT

For handling materials some sort of bin or hopper must be used. The up-to-date contractor has very generally adopted some one of the better types of steel bins. These can be moved from job to job, and, as they last a relatively long time, become a part of the contractor's regular equipment. The homemade bin is going out of use because the measuring devices which may be had with the steel bins are faster, more reliable, and much more accurate. The quicker the operation of the measuring device on the loading bin the less truck time is involved per trip. First-class modern measuring devices on good steel hoppers will measure and discharge a 5-bag batch (sand and gravel) in less than 15 seconds, as indicated by Table 2. As the old-fashioned homemade devices often take a minute or so to load the coarse aggregate and half that time to load the sand, the saving in truck time from the use of modern measuring devices more than offsets their greater first cost.

[1] See the second of this series of articles, PUBLIC ROADS, vol. 6, No. 10, December, 1925.

**Table 2.**—*Stop-watch readings of time required to load a 5-bag batch of sand and gravel from a modern batcher plant to single-batch trucks.*

| Batch No. | Time | Batch No. | Time | Batch No. | Time | Batch No. | Time |
|---|---|---|---|---|---|---|---|
| | *Seconds* | | *Seconds* | | *Seconds* | | *Seconds* |
| 1 | 11 | 19 | 16 | 37 | 17 | 55 | 11 |
| 2 | 22 | 20 | 12 | 38 | 18 | 56 | 10 |
| 3 | 14 | 21 | 12 | 39 | 10 | 57 | 9 |
| 4 | 12 | 22 | 14 | 40 | 8 | 58 | 10 |
| 5 | 10 | 23 | 11 | 41 | 16 | 59 | 14 |
| 6 | 15 | 24 | 12 | 42 | 17 | 60 | 11 |
| 7 | 27 | 25 | 20 | 43 | 14 | 61 | 10 |
| 8 | 6 | 26 | 19 | 44 | 20 | 62 | 12 |
| 9 | 14 | 27 | 9 | 45 | 16 | 63 | 21 |
| 10 | 25 | 28 | 38 | 46 | 13 | 64 | 24 |
| 11 | 17 | 29 | 12 | 47 | 14 | 65 | 13 |
| 12 | 26 | 30 | 8 | 48 | 8 | 66 | 6 |
| 13 | 8 | 31 | 8 | 49 | 13 | 67 | 13 |
| 14 | 13 | 32 | 6 | 50 | 13 | 68 | 25 |
| 15 | 10 | 33 | 9 | 51 | 16 | 69 | 42 |
| 16 | 22 | 34 | 12 | 52 | 12 | 70 | 11 |
| 17 | 10 | 35 | 12 | 53 | 16 | 71 | 12 |
| 18 | 14 | 36 | 15 | 54 | 20 | 72 | 7 |
| Average time required to load sand and gravel | | | | | | | 14.5 |

Accuracy is a vital factor in producing first-class concrete. The right amount of material should be sent out every time. Homemade devices are, in general, definitely inaccurate. The better of the modern hoppers, on the other hand, measure very accurately; and there are now obtainable accurate and thoroughly practical weighing hoppers, and another device which measures the sand under water, a device by which the correct amount of sand and a constant water content are obtained by the same operation.

Of these three systems for measuring aggregate the first, the determination of the batch by measurement, is the fastest. The second, however, is quite fast enough for all practical purposes, as the complete operation of weighing a batch and discharging it is commonly performed in from 40 to 45 seconds. No operation which can be consistently performed in under 1¼ minutes (the standard mixing cycle) need delay the mixer. On the other hand, every operation of this sort does add to the round-trip time of the trucks. But as the weighing can be done between the arrival of trucks, the use of the weighing device does not appreciably affect the trip time of single-batch trucks as compared with their trip time when the measuring device is used, though it does have a slight adverse effect on the trip time where two-batch or larger trucks are used.

The device by which the sand is measured under water is not in common use on highway work. At present it has no particular advantage over the weighing or usual measuring process except at central mixing plants; for, while it perhaps yields a slightly greater accuracy in the determination of the sand content of the mix and a more uniform moisture content in the sand, neither is of much practical value and some rather serious difficulties attend the use of the device under ordinary field conditions. Accuracy in measurement is, of course, desirable, but the accuracy of the weighing process is such that, even with due allowance for variation in the water content of the sand, the error does not often exceed 1 per cent, which is far below the margin of error in other and more important elements in paving work.

A uniform water content in the sand also is highly desirable, but can be of little practical value until the valves in the mixers are so improved that leakage as a common cause of irregularity in the water content is eliminated. Moreover, the high water content in sand which has been measured in this way makes it difficult to handle the cement in the same transportation units, and also increases the lag in discharging the skip at the mixer.

The value of effective modern batch measuring or weighing devices may perhaps be more clearly shown by referring again to the fact that the homemade devices often require as much as a minute for charging a single batch of coarse aggregate and half that time for charging a single batch of sand. With no allowance for the truck time commonly required in getting from the coarse aggregate bin to the sand bin, the time required in loading these materials may, then, reach 1½ minutes per batch, or if 40 batches are poured in an hour, to an hour's truck time per mixer hour. As against this a well-designed modern measuring or weighing device will discharge so quickly that in practice about all that a single-batch truck has to do is to come to a stop and then move off with the load, the next batch being measured or weighed in the interval between the loading of one truck and the arrival of the next. This does not, of course, reduce the time lost to zero, but it comes so close to it that in practice it may take less time to load single-batch trucks from a device of this sort than it does to move them from the coarse aggregate bin to the sand bin of a homemade plant. The saving in truck time which is to be had from the use of a first-class loading device may, then, when operation at the mixer is at a rate as high as 40 batches an hour, be equal to the full time of one single-batch truck. The saving when two-batch trucks are used is quite as important, but does not lend itself as easily to the method of presentation used here. This point should, however, be clear, that savings in truck time obtainable from the use of modern batch measuring or weighing devices are such as to amply justify their cost.

### PRESENT METHODS OF CEMENT HANDLING INEFFICIENT

The most inefficient process on concrete paving jobs to-day is handling the cement. This is still all but universally conducted as a manual operation. Three methods are in common use. By the first the cement is brought to the job in separate trucks, where it is piled along the subgrade; by the second the proper number of unopened sacks are placed on top of the loaded material trucks or cars; and by the third method the proper number of sacks are emptied by hand into the trucks or whatever transportation units are used. Whether the sacks are emptied into the trucks at the cement house or at the mixer, or from the piles along the subgrade into the skip, the operation takes about a minute. If the sacks must be emptied on the truck at the mixer the slightest delay in performing this operation, as when a sack gets buried in the sand, delays the mixer. Similarly, when the sacks are dumped into the skip, if a truck is delayed the operation holds up the mixer, for most inspectors require that the cement be dumped upon the aggreate, refusing absolutely to permit dumping the aggregate upon the cement. In either case the loss of time at the mixer amounts to enough—a minute here and there throughout the day—so that contractors can well afford to consider more effective methods of handling this material.

The operations incident to laying a concrete pavement are such that perfection can be secured only as equipment and methods are perfected and men are thoroughly trained. Specifications do not ordinarily demand perfection. In general they are reasonable, and clearly indicate that all that is expected is work of reasonably attainable quality. Under such conditions the real test of a method or practice is not whether it is perfect, but whether in permitting it there is any real danger that the quality standard established by the specifications and maintained in other parts of the work will be jeopardized. A contractor ought to be permitted to handle his work expeditiously and economically in all of its particulars unless it can be shown that to handle it in this way will clearly result in a finished product which is below standard. The only sound method of determining this is to test any proposed practice in the field, and by so doing to ascertain whether it will produce a product measurably equal to that produced by the methods and practices in vogue.

But whether the contractor's view that the cement ought to be treated as part of the batch or the view that it is deserving of separate and very careful treatment prevails, the fact still remains that cement can be more efficiently handled than is customary at the present time. A number of solutions are possible. A belt conveyer can be installed in the cement house at a reasonable cost to elevate the sacks to a point where the cement can be emptied into hoppers to be dropped by gravity into trucks provided, if need be, with special cement compartments. An installation of this sort recently viewed by the writer required only three men. Cement was trucked from the cars to the conveyer by one man, loaded on the conveyer by another, dumped into the hoppers and the hoppers discharged into the trucks by the third. This arrangement handled the cement successfully up to 225 sacks an hour, which was the greatest demand made upon it. Rather close observation of the work done indicated, however, that it could have met without difficulty the full production demand of 240 bags an hour required for 48 batches an hour.

Nor is there any reason to suppose that hoppers equipped with weighing batch boxes can not be readily adapted to this purpose. If this were done some, at least, of the objections to the shipment of cement in bulk would be overcome. Doubtless other mechanical methods of dealing with the cement problem will be developed, but however this may be, the fact that handling cement now commonly requires about twice as many men as are used in handling five to seven times the weight of aggregate indicates something of the opportunity which there is for saving labor at this point in the paving contractor's work.

A development of the cement-handling problem such as was used in discussing batch measuring and weighing devices would show that at present the truck time involved in handling the cement is about a minute where single-batch trucks are used. To cut this in half would save 20 minutes of truck time per hour if the pouring rate is 40 batches an hour. The belt-conveyer system referred to above required three men as against the five to six commonly employed about the cement house. The saving possible from the device described above is, then, the total time of two men, in some cases three, and at least one-third of the time of one truck. This is quite sufficient to cover the operating cost of the equipment involved, depreciation, interest, etc., and leave a profit for the contractor.

Summarizing the points in regard to material handling which have been touched on above one thing in particular deserves emphasis, namely, that if full production is to be secured no one of the loading operations can be so complicated that the time needed in performing it takes over 1¼ minutes without making this the pace setter for the job. A homemade bin that is so poorly constructed that 1½ minutes are required in loading stone cuts production to 40 batches an hour. A cumbersome method of handling cement may have the same result. A crane so poorly operated that it can not get a batch into the loading bin every 1¼ minutes has the same effect. There is here, then, a sound basis for urging that the best of equipment and the best methods be used in the material yards. On the other hand, every minute saved in performing a service operation such as these also increases the efficiency obtainable from the transportation equipment, which of itself is an important item. But when cumbersome methods reach so far that they reduce the output at the mixer regardless of the transportation available, their cost mounts so sharply that, if competition is keen, no contractor using them can hope to remain long in the business.

#### FORM SETTING AND SUBGRADE PREPARATION

Preparing the subgrade and setting the forms are operations which, in general, do not much interfere with production. Form setting is a manual operation. This is difficult to avoid, as great accuracy is imperative, a satisfactory surface finish being next to impossible of attainment if the forms are carelessly or inaccurately set. Inaccuracy in maintaining the distance between the forms may also cause trouble in the operation of the finishing machine. If the spacing of the forms is wide the wheels bind, if too narrow the finishing machine will run off.

The form setting has been found occasionally to interfere with production because of an inadequate supply of forms, but in such cases the remedy is obvious. Specifications commonly require that forms be left in place 24 hours. It is good practice to set each day the length of form to be used the next. This requires a minimum of twice the daily run, and as a fair margin is always desirable, a form supply of from two and one-half to three times the daily run is apt to prove helpful.

A few years ago finishing the subgrade was almost entirely a manual operation. To-day it is almost as completely a mechanical operation. Unfortunately, however, it has not been standardized. There are, for instance, regions where heavy rolling is an absolute requirement. It matters not at all that the rolling works the subgrade as kneading does putty until it becomes unstable and trucks sink almost to their hubs. The rolling is still insisted upon. There are other regions where heavy rollers are not permitted on the job. Other differences in the treatment of this outstanding important element could be noted, but there is no reason for doing so, as the purpose is merely to suggest that the fact of such wide variations in the treatment of the subgrade indicates a lack of real information concerning what ought to be done to place it in the best condition. To the contractor, however, this difference in specified practices is of more importance, for it is a matter of practical experience with him that the men he has trained to prepare subgrade satisfactorily in one State must be retrained in the next—perhaps even in the next district or the next county. This, of course, slows up operations and increases costs.

But whatever the methods required in finishing the subgrade one modification should be made in dealing with it. It is the common practice to set grade stakes and to finish the subgrade, if this is done some time in advance of surfacing, to the bottom of the concrete paving at the crown. As a result, the whole operation of shaping the subgrade for the concrete slab is one of trenching. The process is expensive, for, while the quantities handled are small, the blade graders used for this purpose carry the cuttings toward the center of the road from which point they must be removed to the shoulders by slip or by fresno. The net result is a triple handling of this material. First, when the grade is built; second, by the blade in cutting it out and throwing it to the center of the road; and third, when it is dragged to the shoulders. It would much simplify this operation if the subgrade were staked to a mean point so calculated that the cuttings from the edge (including the take out for setting the forms) would just make the crown at the center. This practice would lend itself readily to the mechanical methods now in common use in finishing the subgrade and should be in the interest of economy, for, while a little shoulder material would have to be brought in during the final clean up, this could hardly cost as much as it now costs to move this same amount of material three times.

It is appreciated, of course, that the defense of the present practice lies in an assumption that cutting away material as described above leaves a more uniform subgrade condition than could otherwise be attained. If the cutting process were or could be accurately accomplished there would be much merit in this assumption. The fact is, however, that it is not accurately done and in the nature of the case can not be with the tools now available. The blade leaves many high spots and takes out many areas below grade. As a result the only certain results of this practice are a more or less uneven compaction of the surface of the subgrade and a needlessly high cost of operation.

#### SUBGRADE PRACTICE RECOMMENDED

Where specifications will permit the following practices, the fastest and cheapest method of finishing the subgrade is the one described below, which, except as to item 1, is in use in a number of places in the Middle West.

1. Rough grade to mean elevation as described above. Ordinarily a shrinkage factor is allowed when subgrades are laid down in advance of paving, and as this seldom proves to be correct some additional rough grading is likely to be required.
2. With blade, cut slope for extra edge thickness of pavement, cutting wide enough to provide for setting the forms.
3. Trim out for and set forms by hand.
4. Blade material for crown to approximately its final position in the center of the road.
5. Scarify subgrade thoroughly to at least 2 inches below the finished grade.
6. Cut subgrade to exact shape with standard subgrader pulling the machine at least twice to insure a good job. For this work, set the blades from one-quarter to one-half inch high as experience in the particular soil dictates. Roll lightly with a light (1½ to 3 tons) roller. Pull subgrader after rolling with blades set to correct elevation.
7. Back of mixer drag a modern fine finisher to insure that distortion subsequent to preparation of subgrade is eliminated. If the subgrade is of clay or similar material and has been repacked by the trucks, sprinkle heavily under the mixer and on any high spots to facilitate cutting and if the finisher still rides high have four or five men stand on it while it is being pulled ahead by the mixer.

These operations are about as completely mechanical as they can be made at present, are simple and direct, involve the least possible rehandling of material, and result in a subgrade as perfectly shaped as it is now possible to attain on a commercial scale. The one objection likely to be raised is that the scarifying process produces a loose layer under the pavement. Admittedly this is true. Indeed, the process produces a condition quite different from that secured when heavy rolling is required. Extended observation of the use of heavy rollers, however, leaves the impression that where they are used either the actual cross section only roughly approaches that called for on the plans or, and this is probably of much more importance, the tendency is to secure regularity in the final treatment of the cross section by cutting off high spots and filling low spots with the cuttings which are not thereafter as fully compacted as in their first placement. The result is a succession of hard spots and loose areas—not a satisfactory bed on which to place an expensive surfacing. The method outlined above does not wholly correct this difficulty, but its general effect is to procure a more uniform degree of compaction beneath the entire pavement and to produce a condition wherein the effect of filling areas that are a little low is more nearly in keeping with the general condition of the subgrade.

To the contractor an even and exact finish of the subgrade is an important consideration. If he is required to give at least the depth of pavement called for on the plans, as he should be, he ought to be permitted to so handle his subgrade that he will give no more, providing this is possible without endangering the structural integrity of the payment. It is, of course, equally true that if practices are required which make the cost of filling low places with subgrade materials as great as or greater than the cost of filling them with concrete, then the permission to fill them has no practical value. When the use of a heavy roller is specified for the final compaction of the subgrade, a practical solution of this problem of securing a true surface at exact grade at all points is almost an impossibility. But where the method suggested above is used, no such trouble exists, and the contractor is able to give a full depth of pavement and at the same time avoid the use of any considerable excess of materials, which is an important consideration, as a consistent overrun in quantities—even if it amounts only to 2 or 3 per cent—has an important adverse effect on profit.

#### TWO-INCH PIPE LINE MUST GO

The absolute dependence of production on an effective material supply has been emphasized throughout this series of articles. The water used in mixing—and in curing as well—is as truly one of the materials as are cement and stone. With the water as with the stone or the sand, methods of handling and means of delivery are vital factors in efficiency. Only one system of handling water is in common use to-day. It is pumped through a pipe line laid along the right of

way to the mixer. In the common practice provision is made at regular intervals—generally 200 to 300 feet—for taking water from the pipe line, and a hose connection is used to feed the mixer. These hose connections are also used to obtain water for sprinkling and for any other job requirements. A study of the "lost time" on the job [2] will show that the time lost as a result of trouble with the water supply is rather a large item. There is then, ample justification for an analysis of the methods and the equipment in use, for it is quite as essential that the water supply equipment shall be adequate as that the truck supply shall be adequate. Probably from the engineering standpoint it is more important, for, while production is somewhat affected by current practices, quality probably is more affected.

Basically, the water trouble on almost all concrete jobs to-day is inadequate water delivery facilities. With full production, a batch is produced every one and one-fourth minutes. Few jobs, it is true, maintain this rate consistently over any extended period, but a good many reach it not infrequently for a few minutes at a time. This rate, then, sets the water delivery rate. At least one-fourth minute is required in discharging the measuring tank. A full minute is, therefore, all that can be allowed for the delivery of the water for a batch of concrete. A 1-inch slump normally requires between 5 and 6 gallons of water per bag of cement—roughly 30 gallons per standard batch which, under the assumptions made above, is equivalent to 30 gallons a minute. In addition to this, water is required for curing. With full production and a 10-day curing period it will be necessary continually to provide for curing nearly 2 miles or about 20,000 square yards of paving. Rates of production as high as this are rare, but rates of production which will require the proper care of at least 15,000 square yards of paving though not the rule are not uncommon. To cure concrete properly requires that the earth covering shall be kept moist—not merely that it shall be wet down once in a while; and rates of evaporation from loose soil, such as that used for covering the pavement during the curing period, are high. In fact, the evaporation from such soil when the temperature is high, the humidity low, and a brisk breeze is blowing—typical summer conditions over the greater part of the United States—will often exceed one-third of an inch per day and may even exceed a half inch, equivalent to from 2 to 3 gallons per square yard of pavement. These are, of course, the highest rates of evaporation likely to be met but as it is at just these times that full protection of the pavement is most required, they must be considered the governing rates.

[2] See PUBLIC ROADS, vol. 6, No. 9, Nov., 1925, p. 198, Table 3.

Finally, contractors properly prefer to conduct all their operations simultaneously. For that reason, though night sprinkling may at times be practiced, the contractor generally desires to attend to it during the day as the work is then under the observation of his regular foremen. The inspector also has a better grasp on the situation if it is done at that time, and, of course, during very dry weather a night wetting is not sufficient to keep the pavement moist throughout the following day. It is, therefore, proper to view the pavement-curing problem as one which under full production may involve the daily delivery of from 40,000 to 60,000 gallons of water in addition to mixer requirements and even under normal current production standards the daily delivery of from 30,000 to 40,000 gallons of water in excess of mixer requirements.

As shown above, full production at the mixer requires for mixing the concrete a somewhat variable amount not ordinarily exceeding 15,000 gallons per day. For current high rates of production at the mixer the requirement of the mixer seldom exceeds 12,000 gallons a day (10 hours). To these amounts there must be added a somewhat variable amount for wetting down the subgrade. It is therefore apparent that while a pump capable of delivering 100 gallons per minute has sufficient capacity to meet all needs that will ordinarily arise until the production of 18-foot pavement exceeds 750 feet a day, it is apt, at times, to prove inadequate where more than this amount of pavement is being produced unless it is worked a few hours overtime.

One thing, however, must be emphasized—namely, the adequacy of the pumping plant depends absolutely on the use of a pipe line of such size that the pressure head will always be within the limits for which the pump is designed. There are vital differences between a pump designed to deliver 100 gallons a minute against a pressure head of 100 pounds and one designed to deliver at the same rate against a pressure head of 400 pounds. This raises the question as to what pressure head is required in delivering water. Table 3 gives the pressure head in pounds for various rates of delivery in gallons per minute, per mile of common iron pipe such as is generally used on paving jobs and while the pipe is in fair condition. As the pipe becomes somewhat battered, twisted, and rusty with use, the pressure head required to force water through it will increase so that, in a general way, the figures given are minimum figures, which may be exceeded somewhat after the pipe has been in use a few years.

TABLE 3.—*Pressure required at pump for each mile of pipe line to secure desired discharge, through 2, 2½, and 3 inch ordinary iron pipe*[1]

| Diameter of pipe | Number of gallons to be pumped per minute, or per 10-hour day | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20<br>12,000 | 25<br>15,000 | 30<br>18,000 | 35<br>21,000 | 40<br>24,000 | 45<br>27,000 | 50<br>30,000 | 60<br>36,000 | 70<br>42,000 | 80<br>48,000 | 90<br>54,000 | 100<br>60,000 | 110<br>66,000 | 120<br>72,000 |
| | Pressure required at pump, pounds per square inch | | | | | | | | | | | | | |
| 2 inches | 42 | 62 | 88 | 117 | 151 | 188 | 227 | 318 | 421 | 543 | 673 | 820 | 982 | 1,145 |
| 2½ inches | 14 | 21 | 30 | 39 | 50 | 62 | 76 | 106 | 142 | 181 | 224 | 275 | 330 | 385 |
| 3 inches | 6 | 9 | 12 | 16 | 21 | 26 | 32 | 44 | 59 | 75 | 93 | 114 | 137 | 161 |

[1] Based on Williams and Hazen's hydraulic tables.

NOTE.—To obtain the total pressure against which the pump must work, multiply the figures given in the table beneath the desired gallons per minute and opposite the desired diameter of pipe by the total length of the pipe line in miles and then add to this product the figures obtained by multiplying the use of the pipe line in feet from the pump to the discharge end by 0.434.

The pressures given in the table are the number of pounds, as read on the gauge at the pump, which be required to deliver the stated number of gallons per minute at the outflow end of a pipe line 1 mile long. Thus, if 50 gallons per minute are required and a 2-inch pipe a mile long is to be used, the gauge at the pump must be run up to 227 pounds. If 100 gallons are desired 1 mile from the pump and a 2-inch line is used, the gauge pressure at the pump must be run up to 820 pounds, and if this rate of delivery were required 3 miles from the pump the gauge pressure would have to be run up to 2,400 pounds. Of course, neither ordinary pipe nor ordinary pumps will stand any such pressures. The point, however, is that here is the explanation of the poor water supply so common on paving jobs to-day. Contractors are attempting the impossible. A fully adequate water supply for maximum requirements simply can not be driven through a 2-inch pipe 2 or 3 miles long. If the pump were strong enough to do it, the pipe would not stand it. The remedy lies in a larger pipe. One hundred gallons of water per minute can be driven through nearly 2 miles of 3-inch pipe with the same gauge pressure—i. e., the same effort on the part of the pump—which is required to drive it one-quarter mile through a 2-inch pipe.

With no other consideration than the water supply for the mixer, contractors could well afford to use 3-inch pipe, for its use would result in a water delivery at a pressure far less destructive of pumps, line, hose, mixer valves, etc. The added cost of pumping enough for adequate curing and, subgrade sprinkling would be so slight that the problem would cease to be troublesome, and there would probably be much less demand for permission to use chemicals as curing agents. Three-inch pipe costs about twice as much as 2-inch pipe. The change to the larger size is not, therefore, prohibitively expensive and, as suggested above, delays due to a poor water supply would be of such reduced importance as probably to much more than offset the extra outlay.

In addition to reducing lost time at the mixer, the installation of the 3-inch pipe would permit the use of relief valves which would protect the pipe line, hose, and mixer valves against excessive pressure. Gauges should also be installed at the pump, and instead of permitting pumps to run wide open their speed should be controlled according to the rate of delivery desired and the distance this delivery must be pumped. Thus, as an illustration, if the maximum water requirement is 60 gallons per minute through 2 miles of 3-inch pipe line, the pumping engine should be cut down to a speed which will produce a pressure of about 150 pounds at this delivery. The relief valve at the pump should then be set at slightly above this pressure, while the relief valve at the mixer might be set at 50 pounds or even less. This practice saves wear and tear on the pump and tends to avoid the break downs which occur most frequently when machines operate close to or above rated capacity.

The conclusion is that contractors should abandon the 2-inch pipe line and that engineers drawing specifications for paving work, if water is to be used in curing the pavement and wetting the subgrade, should give the same attention to insuring adequate pipe lines that is given to the equipment question in other phases of the work.

#### SUBGRADE TRIMMING DELAYS EASILY AVOIDED

The operations incident to the final fine finishing of the subgrade are performed after the mixer is moved and before concrete is placed. At this time the parting strip is placed, if one is used, and the reinforcing laid. Transverse joints are also placed at this time. These operations may take considerable time and so they sometimes hold up the mixer. A very simple expedient will avoid such delays. The boom on the mixer is about 20 feet long. Where these operations take up more time than can be had while a single batch is being mixed, it is good practice to move after every fourth batch. Four 5-bag batches will lay about 9 feet of pavement of standard 18-foot, thickened-edge section. Each move should, therefore, cover a distance of about 9 feet, and the move should leave the end of the boom as near the end of the last strip as possible. By proceeding in this manner, there always will be when the move is completed a strip of proper length (about 9 feet) at the end of the boom on which all finishing operations are completed, steel laid, parting strip and transverse joint in place, and a 10 to 12 foot space in which to work on the preparation of these items preparatory to the next move. This method, under full production, allows five minutes for final subgrading, laying reinforcing steel, parting strip, and setting transverse joint, which is a sufficient lenght of time if the men are well trained and the inspection is reasonable.

Ordinarily there is little trouble about the reinforcing steel or the final fine finish of the subgrade, but the parting strip is the source of a good deal of trouble. The cause may be traced generally to the fact that the inspector wants the parting strip set on an absolutely straight line, whereas the specifications commonly permit the use of a parting strip which is so thin that this becomes practically impossible of attainment. A more rational treatment of this matter, particularly where a finished center joint is used, would be a somewhat heavier parting strip, set slightly below the surface, capped with a fairly heavy removable crown strip, the joints of the latter being so spaced as not to fall on the parting strip joints. If, then, a good gauge is used in setting the parting strip, straight alignment can be secured.

Neither the organization of the finishing operations nor the equipment are the source of much, if any, reduction in output. They can, however, be conducted more efficiently. Such losses as result from materials pushed over the forms or otherwise spilled or wasted can be eliminated. They result from poor dumping and do not occur where there is a first-class mixer operator and a good operator on the finishing machine.

When the concrete is deposited on the subgrade it may be merely dumped in a pile, or it may be roughly spread, or, if the mixer operator really knows his business, it may be placed so nearly in correct position that it needs almost no attention from the puddlers. In case concrete of proper consistency is merely dumped, four puddlers will be worked almost to exhaustion to get it into position for the finishing machine; if a fair effort is made to spread the concrete, three men can do the work of puddling rather more easily than four will do it if no effort is made to spread it. If the mixer operator is a real expert he can place the concrete so well that two men will find it easy to

handle the work of puddling. One could, in fact, do all the work if it were not for the necessity of running back and forth across the pavement in spading forms, looking after the requirements of the finisher, etc.

This not only serves to illustrate in another way the value of a good mixer operator, but what is of more importance, the value of complete and detailed training of operatives with a view to making the correct performance of one operation facilitate the correct performance of another. If the concrete is properly placed by the mixer operator, the labor of preparing it for the finisher is reduced. If it is uniformly mixed to the proper consistency, the work required in producing a proper surface is reduced. More illustration would serve only to add emphasis to the fact, outstandingly true of concrete paving work, that the total labor requirement is visibly affected by the study given to the perfection of methods, as well as to how the performance of one operation affects the labor requirements of another. Whether the men are trained to perform the various operations correctly or left to work out their own ideas as to how each specific task should be performed also affects the amount of labor required. Where no attention is given to these matters, it may still be possible to get high production—even full production—but this will be attended by the use of a good deal of extra labor. In any effort to secure high efficiency, it is necessary to go beyond the mere question of production and ascertain whether this production is arrived at through carefully studied processes which reduce the work to be done to a minimum or merely through the use of excessive labor and equipment.

#### THE FINISHING METHOD

Back of the puddlers, the concrete is put into shape by a finishing machine. These are of two general types—the tamping finishers and the sliding finishers. Both do good work, but as the sliding machines are substantially built, work quietly, and, on the whole, require less effort on the part of the puddlers they have proved very popular. Moreover, if the consistency of the concrete is correct and uniform these machines will produce a surface so accurate that one man with a long-handled float can do all the necessary finishing and check the work with a 10-foot straightedge, calling on one of the other laborers to help when the belt is to be pulled. This is the simplest finish which has been observed, the cheapest, and so fast that it need never lag a half hour behind the mixer. Moreover, it not only produces a very smooth pavement but does so without that long-continued working of the surface incident to some systems of finishing, which is at least in part responsible for scaling.

Here again there is an illustration of the correlation of effort necessary in order to produce a high-class product expeditiously. The success of this method and the economy it makes possible depend on two things—a proper consistency (about 1-inch slump) and uniformity in consistency. Without these the method fails. Incidentally, it may be remarked that contractors often object to a dry mix on the ground that it is hard to handle. This is not necessarily the case, but often seems to be so because a better mixer operator is required to handle the dry batch properly, and if it is not properly handled a large amount of extra work for the puddlers does result. The consistency is therefore criticized though in fact the mixer operator rather than the mix is at fault. What the contractor quite generally overlooks is that even if some extra work is thrown onto the puddlers, this is more than made up in faster and easier finishing, for where a wet concrete is used the finishing is slow and it becomes a difficult matter to secure a smooth surface. There is also trouble when some batches are wet and some dry. The wet batches settle a little while the dry batches (1-inch slump) do not settle appreciably after they are finished. The result is that direct settlement and the tendency of the wet concrete to flow after it is placed make it necessary to correct certain irregularities in the surface finish which do not appear at all when a concrete of proper and uniform consistency is used. This is outstandingly true on grades. If the consistency is right the tendency to flow ceases to be a problem.

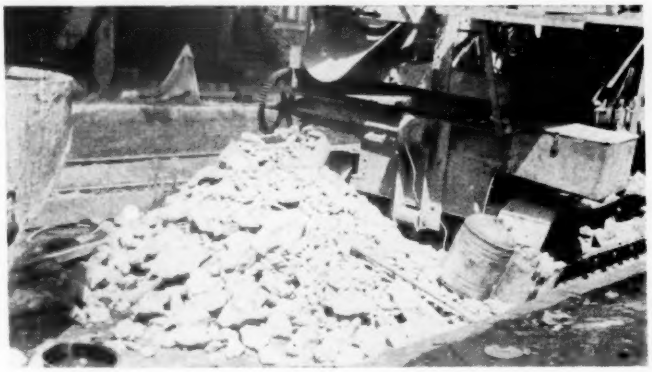

FIG. 1.—Material removed in cleaning out mixer. Some of the blades were not visible when cleaning out was started

The above deal with some of the more important aspects of the work of the various component parts of a paving organization. Before turning to a discussion of what constitutes a proper personnel and equipment for a paving organization—matters that will be discussed in the next article—comment may be made on a few observed conditions as they affect concrete paving work. The first of these is that manufacturers would do well to inform contractors more fully concerning the spare parts which ought to be kept on hand. Ordinarily, a high percentage of all repairs involve a relatively small number of parts. On some types of mixers the cables break often. On cranes the cables and the sheaves usually give trouble. These are merely illustrative. Every manufacturer has records which show, or can be made to show, just what parts are most likely to cause trouble, and he can, if he will, tell the contractor who buys his machine which parts he ought to carry on hand as insurance against delay in case of a breakdown.

There is no machine on the market to-day so consistently designed that it will wear out without breakdowns, even if operated under ideal conditions, to say nothing of the conditions under which its work will actually be performed. Therefore, in the interest of reducing those delays due to breakdowns which are known by manufacturers to be of relatively common occurrence, they could greatly assist contractors by preparing a list of the spare parts which, in the contractor's own interest, should be on the job at all times. It should be remembered that on work of this kind the saving of an hour's mixer time, which would otherwise be lost waiting for repair parts, will ordinarily pay interest charges on a $500 investment in spare parts.

But the contractor can select these parts intelligently only after years of experience. The manufacturer is always a better judge of what parts should be on hand. His records form a sound basis for his judgment. He should, therefore, look to this matter as carefully as to the original sale. Nor should he feel that an admission that repair parts are likely to be necessary will injure sales. Every contractor knows that equipment will break down and the assistance to be had from a really well-selected list of spare parts would much more probably be accepted as a valuable service.

Another matter of general application is that the quality of the concrete is affected by the efficiency with which it is mixed. Omitting from consideration here the relative efficiency of the various types of mixers, the fact remains that a good deal of concrete of reduced quality is being produced through the use of mixers in which the blades have become badly worn or which have accumulated so much concrete on the inside of the drum that the mixing is poorly done. Figure 1 shows the material removed from such a mixer. In this particular case some of the blades were completely buried when the clean out was started.

In addition to accumulations in the mixer, accumulations all over the outside of the mixer are the rule rather than the exception. The contractor, who rides to work every morning in a well-kept car, allows his mixer, worth two or three times as much, to go uncleaned for weeks at a time. This is regretable, for, though neither the mixer nor any of the other equipment is as fine looking as the car, its proper care is quite as essential and the longer life that may be expected to result from such care is likely to more than repay its cost.

#### BETTER SUPERINTENDENCE THE PRIMARY NEED

Another matter that should be noted is that in all of these studies the objective has been a determination of what causes interfere with securing a full output while the mixer is working. There is also a series of causes affecting the number of hours worked that is not treated in this series of articles. It is commonly presumed that the effect of these causes of lost time is unavoidable, but the experience which the bureau's representatives have had in applying the data which has been secured in these studies in improving production has seemed to indicate that while many of the delays resulting from these causes are unavoidable some of them are not. This matter will be left for further discussion when more data are obtained.

Finally, the discussion of the causes affecting production would be incomplete without at least a brief mention of superintendence. Any construction operation divides itself naturally into at least three fields. There is first what may be termed the labor field—the work which must be done and its immediate direction. This field is occupied by common labor and skilled labor of various kinds and is directed by the various foremen. The next generally recognized field involves the business side of the work. This covers getting the work, handling the financing, and looking after the purchase of materials, securing labor, etc., in short, whatever business transactions are involved. The third field covers planning the work in its various aspects, studying methods, keeping the various operations in balance; in short, all matters that make for a more efficient conversion of raw materials into the finished product. This is superintendence. The difficulty in securing competent superintendence seems to be that the position really requires a combination of engineering training, vigorous, aggressive ability to handle men, intimate knowledge of the practical side of construction work, and courage to put into effect new ideas when it is known that these are right. That there is real profit to be had from employing an able superintendent may be seen from the fact that on a job where a superintendent meeting these requirements was employed the production of the single 5-bag paver in use averaged 95 feet of 18-foot slab an hour during the nearly 23 days (of 10 hours) it was possible to work during the month of July and that during a week's study in August production averaged a little over 100 feet an hour.

While the delays that have been discussed in this series of articles are the immediate cause of low production, the conclusion is unavoidable that most of them would long since have been greatly reduced if more attention had been given by contractors to securing really competent superintendents. As a matter of fact, superintendency is really an engineering field and young engineers who possess the proper qualifications would do well to consider the opportunities that this field offers. Contractors also might do well to consider more seriously the advisability of securing, even at some temporary financial sacrifice to themselves, men who are technically and mentally fitted to meet adequately the real responsiblities of superintendency. For at present it does not appear probable that most road construction work will be raised to that degree of efficiency which is reasonably possible until better men are more generally employed as superintendents.

# PROTECTION OF CONCRETE AGAINST ALKALI

## CONTINUATION OF TESTS BY BUREAU OF PUBLIC ROADS ON TREATMENT OF CONCRETE WITH TARS AND PARAFFIN

**Reported by E. C. E. LORD, Petrographer, United States Bureau of Public Roads**

IN AN earlier publication on the protective effect of tar and paraffin on concrete, the results of tests covering a period of approximately one year were recorded.[1] These investigations have been continued during the succeeding year and a summary of the results thus far obtained is given in the present report.

The method of treatment has been described in detail in the earlier publication and is, therefore, only briefly reviewed in the following:

Portland cement concrete cylinders (4 by 6 inches) were made up to normal consistency with Potomac River sand and gravel and graded in the proportions 1:1½:3, 1:2:4 and 1:3:6 and cured for 28 days in damp sand and about four weeks in dry air. The cylinders were all treated in batches of four each, some receiving 6 and 10 coats of water-gas tar alone while one batch from each mix was painted with 10 coats of water-gas tar followed by a seal coat of heavy coal tar cut back to working consistency with solvent naptha. The paraffin treatment consisted in immersing the test specimens of each mix for 24 hours in a 20 per cent paraffin-kerosene solution at about 80° F. and applying 4 coats of the same solution after the cylinders had dried out for one week. In one instance (1:2:4) the paint coats were omitted.

Two batches from each mix were left untreated as checks, one to be stored in alkali solution and the other in tap water.

The physical properties of the tars employed are given in Table 1.

TABLE 1.—*Properties of tars*

| | Water-gas tar | Coal tar |
|---|---|---|
| General characteristics | Very thin liquid | Sticky semisolid. |
| Specific gravity (25° C.) | 1.053 | 1.268. |
| Specific viscosity | 3.17 at 25° C | |
| Float test (50° C.) | | 694 sec. |
| Softening point ( ° C.) | | 45. |
| Total bitumen soluble in $CS_2$ | 96.99 per cent | 74.22 per cent. |
| Free carbon | 0.30 per cent | 25.62 per cent. |
| Inorganic matter (insoluble) | 0.05 per cent | 0.16 per cent |
| Water | 2.66 per cent | |
| Distillation, total to 300° C | 42.20 per cent | 19.0 per cent. |
| Residuum | 57.80 per cent (semi-solid). | 81.0 per cent (solid). |
| Specific gravity of distillate (25° C.) | 0.956 | |

### EXPOSURE TESTS

All samples were weighed before and after treatment, and stored, four each, in porcelain-lined, covered cans containing 6,000 cubic centimeters of a 3 per cent sodium-magesium sulphate solution. This solution was frequently renewed and the test specimens removed at weekly, monthly, and trimonthly periods and allowed to dry out for 48 hours before returning to the alkali bath.

At the end of the two years all samples were removed from the solution, weighed, and allowed to dry out for 10 days in the laboratory when approximately constant weight was obtained. The difference between this weight and that immediately after removal from the bath indicated capillary or absorbed moisture, while the original weight before immersion deducted from that after immersion and drying represented the quantity of secondary salts formed during the test period. These secondary salts together with the lime dissolved from the test specimens during the period of immersion, as well as insoluble residues found in the cans, served as a measure of alkali attack.

During the early stages of the investigations it was noted that the lime dissolved from the untreated test specimens gradually decreased in quantity until after a period of about three months it was entirely removed from solution. This loss in lime was accompanied by the loss of an equivalent amount of magnesia and by the formation of carbonates of lime and magnesia, and finally of calcic sulphoaluminate. It may be a matter of interest to state that the latter salt was found only as a precipitate in the cans and not in the concrete itself, thus indicating that the failure of concrete under the present test conditions must be attributed to other agencies. In the present instance the destructive compounds have been found to be magnesium hydrate and gypsum which are formed immediately when free lime, developed in the cement on setting, is brought in contact with solutions containing magnesium sulphate. This was found to be especially noticeable in imperfectly seasoned concrete, where the colloidal magnesium hydrate and gypsum crystals forming in the body of the concrete caused within three months sufficient volume change to rupture the specimens. In well-seasoned concrete, on the other hand, the formation of calcium carbonate during the curing period retarded the entrance of dissolved salts thereby reducing the potency of alkali attack.

In this connection it may be of interest to refer briefly to the chemical reactions taking place under the present test conditions. Free lime developed in the cement on setting combines with magnesium sulphate to form gypsum and magnesium hydrate. The latter salt takes up $CO_2$ from the solution and is converted to magnesium carbonate and finally to bicarbonate, which passes into solution and reacts with gypsum to form magnesium sulphate and calcium bicarbonate. The latter salt is unstable in solutions containing magnesium carbonate and is precipitated as normal carbonate cf lime or calcite.

At the end of the two-year period the untreated test specimens were found to be incrustated with carbonate of lime and magnesia, but showed no marked indication of failure through alkali attack. For this reason it was considered advisable to postpone physical tests on all samples until decided evidence of failure occurred.

### RESULTS OF TESTS

The tests thus far carried out are of a chemical nature and serve to indicate, through gain in weight by accumulation of secondary salts and absorbed moisture and loss of soluble material, the extent of alkali attack, as well as the degree of protection offered by the various treatments.

[1] Protection of Concrete Against Alkali, PUBLIC ROADS, vol. 5, No. 3, May, 1924.

TABLE 2.—*Action of alkali solution on concrete treated with tar and paraffin after two years' exposure*

| Batch No. | Mix | Treatment | Weight after treatment | Tar absorbed | Paraffin absorbed | Weight after 2 years in solution | Moisture absorbed | Secondary salt | Tota gain | Total loss |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Grams* | *Per cent* | *Per cent* | *Grams* | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| 1 | 1:1½:3 | Untreated | 10, 683 | | | 11, 105 | 0.77 | 3.18 | 3.95 | 0.16 |
| 2 | 1:1½:3 | 6 coats water-gas tar | 10, 641 | 0.49 | | 10, 859 | .58 | 1.48 | 2.06 | .08 |
| 3 | 1:1½:3 | 10 coats water-gas tar | 11, 129 | .82 | | 11, 322 | .47 | 1.27 | 1.74 | .09 |
| 4 | 1:1½:3 | 10 coats water-gas tar; 1 coat coal tar | 11, 326 | 1.12 | | 11, 429 | .27 | .64 | .91 | .02 |
| 5 | 1:1½:3 | 24 hours in paraffin solution | 11, 463 | | 1.84 | 11, 601 | .34 | .86 | 1.20 | .07 |
| 6 | 1:1½:3 | 24 hours in paraffin; 4 coats of paraffin | 11, 411 | | 2.32 | 11, 524 | .32 | .68 | 1.00 | .03 |
| 7 | 1:2:4 | Untreated | 10, 687 | | | 11, 185 | .66 | 4.06 | 4.66 | .19 |
| 8 | 1:2:4 | 6 coats water-gas tar | 10, 872 | .46 | | 11, 178 | .31 | 2.50 | 2.81 | .17 |
| [1] 9 | 1:2:4 | 10 coats water-gas tar | 8, 293 | 1.29 | | 8, 428 | .30 | 1.66 | 1.96 | .07 |
| 10 | 1:2:4 | 10 coats water-gas tar; 1 coat coal tar | 11, 053 | 1.46 | | 11, 178 | .23 | .90 | 1.13 | .04 |
| 11 | 1:2:4 | 24 hours in paraffin; 4 coats of paraffin | 11, 598 | | 2.62 | 11, 724 | .26 | .83 | 1.09 | .03 |
| 12 | 1:3:6 | Untreated | 10, 410 | | | 10, 967 | .15 | 4.20 | 5.35 | .26 |
| 13 | 1:3:6 | 6 coats water-gas tar | 10, 505 | .64 | | 10, 847 | .63 | 2.63 | 3.26 | .15 |
| 14 | 1:3:6 | 10 coats water-gas tar | 10, 852 | 2.26 | | 11, 147 | .75 | 1.97 | 2.72 | .11 |
| 15 | 1:3:6 | 10 coats water-gas tar; 1 coat coal tar | 10, 887 | 2.94 | | 11, 045 | .43 | 1.03 | 1.46 | .07 |
| 16 | 1:3:6 | 24 hours in paraffin; 4 coats of paraffin | 11, 415 | | 2.77 | 11. 600 | .58 | 1.13 | 1.71 | .03 |

[1] Batch contained 3 cylinders.

In Table 2 are given in condensed form the results of exposure tests after a period of two years, together with the quantities of tar and paraffin absorbed, determined on a per-cent-by-weight basis. It will be noticed that the amount of protectives taken up increases with leanness of the mix and might serve as a measure of density for concrete.

Considering the quantitative effect of alkali attack it will be noted that the total percentage of gain and loss, indicated in the last two columns of the table, increases with the leanness of the mix and decreases with the quantity of protectives applied.

An interesting point is the very small percentage of dissolved material as compared to the large increase of secondary salts, chiefly carbonates of lime and magnesia and hydrated alumino silicates of lime, which exceed 4 per cent in the untreated 1:3:6 specimens (No. 12).

The amount of absorbed moisture is quite low in all samples and varies from about one-fourth to one-sixth that of secondary salts in the untreated specimens.

Regarding the relative protection offered by the various treatments, as indicated by percentage gain and loss, it will be noticed that samples of all mixes receiving 10 coats of water gas tar followed by a seal coat of coal tar (Nos. 4, 10, and 15), and those immersed 24 hours in the paraffin-kerosene solution and painted with four coats of this solution (Nos. 6, 11, and 16) show about equal resistance to alkali attack.

It will be observed also that where the surface coats have been omitted the indicated protection has been reduced nearly one-half in the case of tar (Nos. 3, 9, and 14) and about one-sixth in that of paraffin (No. 5).

As stated in a previous report, the effect of alkali attack on samples immersed in paraffin appeared to be mainly surficial, which is further substantiated by the relatively high total loss (0.07 per cent) and low percentage of absorbed moisture indicated in No. 5.

Comparing the total gain and loss of material from the untreated samples of all mixes (Nos. 1, 7, and 12) with that from samples receiving the most liberal tar and paraffin treatment (Nos. 4, 6, 10, 11, 15, and 16) the degree of protection offered by the latter would indicate at least a fourfold prolongation of the life of concrete subjected to alkali attack under conditions similar to those described.

## EFFECT OF SIZE AND SHAPE OF TEST SPECIMEN ON COMPRESSIVE STRENGTH OF CONCRETE

Data of interest to those engaged in the testing of concrete will be found in Bulletin 16 of the Structural Materials Research Laboratory, Lewis Institute, Chicago, "Effect of Size and Shape of Test Specimen on Compressive Strength of Concrete," by Harrison F. Gonnerman. Tests were made on 1,755 concrete specimens at ages of 7 days to 1 year in a study of the compressive strength of—

(1) Cylinders 1½ to 10 inches in diameter, 2 diameters long.
(2) Cylinders 12 inches long, 3 to 10 inches in diameter.
(3) Cylinders 6 inches in diameter, 3 to 24 inches long.
(4) Cubes, 6 and 8 inches.
(5) Prisms, 6 by 12 and 8 by 16 inches.

The relative strength of the different forms of specimen was compared with the strength of 6 by 12 inch cylinders from the same concrete.

The principal conclusions are:

1. The 6 by 12 inch cylinder generally used for compression tests of concrete, as recommended by the American Society for Testing Materials, is a satisfactory form of specimen. However, this size of cylinder should be limited to aggregates not larger than 2 inches in diameter.

Four by 8 inch or 5 by 10 inch cylinders are suitable for the smaller sizes of aggregate. The ratio of diameter of cylinder to maximum size of aggregate should be not less than about 3. For aggregates larger than 2 inches, 8 by 16 inch cylinders or larger should be used.

2. For cylinders of length equal to 2 diameters, lower strengths were generally obtained with the larger cylinders. The decrease in strength with size of cylinder was not important for diameters of 6 inches or less; 8 by 16 inch and 10 by 20 inch cylinders gave 96 and 92 per cent of the strength of 6 by 12 inch cylinders.

3. Concrete cylinders having a ratio of length to diameter of from 0.5 to 4 gave the following average strength ratios at 28 days:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Ratio of length to diameter | 0.5 | 1.0 | 1.25 | 1.5 | 2.0 | 3.0 | 4.0 |
| Strength-ratio, percentage of strength of 6 by 12 inch cylinder | 178 | 115 | 107 | 103 | 100 | 95 | 90 |

These strength ratios agree with those reported by other investigators. The difference in strengths of cylinders having ratios of length to diameter between 1.5 and 2.5 was not important.

4. The 6 and 8 inch cubes tested at ages of 7 days to 1 year gave strengths averaging 18 and 13 per cent higher than 6 by 12 inch cylinders. The strengths for 6 by 12 and 8 by 16 inch prisms were lower at all ages than that for 6 by 12 inch cylinders; the strength ratios averaged 93 and 91 per cent, respectively.

5. For all forms of specimens the compressive strength increased with age for moist curing. For cylinders and prisms of length equal to twice the diameter or width, the 7-day, 3-month and 1-year strengths averaged 52, 142, and 178 per cent of the 28-day strength for 1:5 concrete. The corresponding percentages for 6 and 8 inch cubes were 60, 129, and 165.

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# UNITED STATES DEPARTMENT OF AGRICULTURE

## BUREAU OF PUBLIC ROADS

# STATUS OF FEDERAL AID HIGHWAY CONSTRUCTION

AS OF

DECEMBER 31,1925

| STATES | FISCAL YEARS 1917-1925 | | | FISCAL YEAR 1926 | | | | | | | | | BALANCE OF FEDERAL AID FUND AVAILABLE FOR NEW PROJECTS | STATES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PROJECTS COMPLETED PRIOR TO JULY 1, 1925 | | | PROJECTS COMPLETED SINCE JUNE 30, 1925 | | | *PROJECTS UNDER CONSTRUCTION | | | PROJECTS APPROVED FOR CONSTRUCTION | | | | |
| | TOTAL COST | FEDERAL AID | MILES | TOTAL COST | FEDERAL AID | MILES | ESTIMATED COST | FEDERAL AID ALLOTTED | MILES | ESTIMATED COST | FEDERAL AID ALLOTTED | MILES | | |
| Alabama | $ 5,970,097.71 | $ 2,863,197.86 | 611.8 | $ 6,885,939.73 | $ 3,269,191.85 | 398.3 | $ 8,704,688.62 | $ 4,237,217.26 | 431.0 | $ 953,521.93 | $ 431,936.34 | 28.2 | $ 3,547,911.69 | Alabama |
| Arizona | 9,580,133.43 | 5,016,119.94 | 613.8 | 938,773.23 | 573,458.56 | 80.4 | 1,276,105.71 | 834,777.12 | 92.7 | 176,977.10 | 108,150.70 | 26.7 | 3,084,742.68 | Arizona |
| Arkansas | 13,310,190.08 | 5,380,181.73 | 1,048.9 | 3,064,835.14 | 1,318,794.44 | 130.0 | 6,325,715.91 | 3,034,237.17 | 423.8 | 740,437.29 | 337,838.89 | 52.4 | 1,534,751.77 | Arkansas |
| California | 22,346,175.99 | 10,719,249.61 | 894.8 | 2,036,363.75 | 911,402.63 | 47.4 | 12,008,360.50 | 5,900,537.89 | 364.7 | 488,875.22 | 293,325.11 | 16.6 | 4,248,299.76 | California |
| Colorado | 11,876,703.94 | 6,067,814.34 | 651.2 | 918,425.72 | 492,407.79 | 37.7 | 4,450,923.10 | 2,226,006.88 | 238.0 | 453,284.06 | 254,212.34 | 23.8 | 3,285,370.65 | Colorado |
| Connecticut | 4,558,639.29 | 1,819,368.66 | 101.6 | 750,965.91 | 280,212.14 | 13.4 | 1,901,818.16 | 580,259.68 | 29.1 | 238,929.61 | 62,777.95 | 3.7 | 1,611,062.57 | Connecticut |
| Delaware | 4,281,559.81 | 1,496,190.65 | 107.1 | 455,744.13 | 212,544.95 | 12.3 | 980,042.66 | 388,784.75 | 22.7 | 445,559.65 | 9,000.00 | 10.5 | 367,537.65 | Delaware |
| Florida | 2,959,273.72 | 1,405,487.97 | 96.3 | | | | 10,810,470.04 | 4,976,998.29 | 289.3 | 863,763.25 | 301,557.00 | 20.1 | 1,400,910.74 | Florida |
| Georgia | 20,156,002.37 | 9,406,366.46 | 1,478.3 | 2,661,700.61 | 1,290,934.25 | 157.0 | 11,066,415.53 | 5,284,563.06 | 699.0 | 1,168,539.91 | 519,002.21 | 86.5 | 1,931,087.02 | Georgia |
| Idaho | 9,394,676.80 | 4,815,332.26 | 600.1 | 211,619.32 | 121,958.48 | 24.6 | 3,192,163.48 | 2,003,022.53 | 206.0 | 626,051.34 | 347,904.45 | 17.0 | 1,271,409.28 | Idaho |
| Illinois | 40,010,481.10 | 18,640,076.28 | 1,236.2 | 933,608.56 | 447,871.39 | 32.1 | 8,385,606.20 | 4,070,001.59 | 284.9 | | | | 6,674,248.74 | Illinois |
| Indiana | 13,639,172.65 | 6,562,455.68 | 422.1 | 1,132,976.57 | 544,542.84 | 41.2 | 17,995,239.73 | 8,445,342.09 | 492.9 | 543,575.62 | 269,346.52 | 16.6 | 2,382,667.87 | Indiana |
| Iowa | 27,272,285.21 | 11,107,492.99 | 1,996.9 | 722,462.52 | 320,365.06 | 36.5 | 7,616,193.14 | 3,424,369.59 | 471.5 | 1,264,775.81 | 604,703.90 | 139.5 | 4,028,631.46 | Iowa |
| Kansas | 26,309,695.77 | 9,755,273.32 | 831.4 | 3,426,659.54 | 1,511,580.70 | 206.1 | 10,389,493.27 | 4,407,028.64 | 491.8 | 3,107,841.01 | 716,697.19 | 165.5 | 3,073,831.15 | Kansas |
| Kentucky | 14,832,324.28 | 6,205,994.59 | 584.9 | 2,307,684.84 | 925,345.04 | 88.4 | 7,570,945.74 | 3,418,811.07 | 302.1 | 352,618.16 | 176,309.07 | 16.8 | 2,486,349.23 | Kentucky |
| Louisiana | 11,939,424.97 | 5,279,870.86 | 927.6 | 875,723.58 | 411,312.04 | 65.0 | 3,216,745.85 | 1,546,809.17 | 144.0 | 356,130.73 | 178,065.36 | 2.8 | 1,856,350.57 | Louisiana |
| Maine | 8,174,281.31 | 3,907,870.33 | 281.4 | 249,291.85 | 123,602.05 | 9.8 | 2,046,840.72 | 825,486.82 | 66.2 | 188,780.85 | 94,390.42 | 8.4 | 1,513,478.38 | Maine |
| Maryland | 8,132,506.90 | 3,849,383.15 | 294.4 | 396,647.75 | 191,101.96 | 15.7 | 2,783,283.46 | 1,229,741.15 | 125.3 | | | | 654,830.74 | Maryland |
| Massachusetts | 14,047,656.22 | 5,467,661.28 | 300.6 | 751,829.45 | 271,111.11 | 20.4 | 6,104,839.26 | 1,591,752.67 | 80.4 | 323,229.34 | 105,000.00 | 5.3 | 2,673,200.94 | Massachusetts |
| Michigan | 16,234,000.80 | 7,328,316.91 | 612.6 | 6,532,163.80 | 3,001,329.49 | 251.8 | 11,328,019.35 | 5,200,570.40 | 300.8 | 501,034.00 | 208,769.57 | 11.9 | 4,603,378.63 | Michigan |
| Minnesota | 30,415,685.89 | 12,738,642.04 | 2,721.2 | 5,271,152.99 | 2,284,974.52 | 397.0 | 6,805,245.59 | 2,356,400.00 | 522.3 | 1,401,252.64 | 99,900.00 | 14.7 | 2,111,863.44 | Minnesota |
| Mississippi | 10,292,285.79 | 4,988,702.73 | 803.4 | 1,654,221.80 | 826,149.19 | 130.0 | 8,224,065.64 | 4,105,777.15 | 433.2 | 1,182,747.52 | 508,930.85 | 62.6 | 1,698,458.08 | Mississippi |
| Missouri | 17,368,156.57 | 8,219,411.43 | 1,118.9 | 3,849,489.25 | 1,863,218.92 | 173.4 | 25,608,480.96 | 10,054,952.66 | 716.5 | 1,134,406.92 | 48,617.89 | 29.2 | 2,600,235.10 | Missouri |
| Montana | 10,156,600.41 | 5,317,523.15 | 921.6 | 656,240.07 | 500,897.10 | 62.2 | 1,793,440.55 | 1,314,400.11 | 182.0 | 1,038,259.42 | 577,318.37 | 121.1 | 5,714,746.27 | Montana |
| Nebraska | 9,306,374.36 | 4,389,523.50 | 1,570.6 | 1,521,442.87 | 736,793.25 | 120.3 | 10,699,742.91 | 5,302,274.70 | 1,071.0 | 532,413.63 | 264,802.55 | 49.3 | 3,941,841.00 | Nebraska |
| Nevada | 5,917,465.69 | 3,088,299.78 | 357.3 | 1,162,534.50 | 974,820.36 | 95.6 | 4,403,970.68 | 3,682,501.37 | 398.0 | | | | 1,049,593.49 | Nevada |
| New Hampshire | 4,165,687.86 | 1,986,226.87 | 208.1 | 568,463.14 | 264,530.20 | 20.2 | 853,156.53 | 402,397.54 | 26.9 | 9,979.13 | 4,989.56 | 0.5 | 511,347.83 | New Hampshire |
| New Jersey | 11,961,357.45 | 3,820,679.99 | 219.1 | 1,844,539.28 | 495,438.46 | 29.4 | 8,744,958.07 | 3,165,620.72 | 62.1 | | | | 985,680.83 | New Jersey |
| New Mexico | 8,717,999.18 | 4,914,070.61 | 1,081.3 | 3,303,452.65 | 2,171,539.76 | 301.7 | 1,669,256.11 | 1,089,644.56 | 144.2 | 74,555.37 | 46,757.90 | 5.4 | 2,750,373.17 | New Mexico |
| New York | 28,597,769.67 | 12,229,076.63 | 831.5 | 6,679,700.73 | 2,743,080.08 | 168.8 | 32,742,525.75 | 9,904,624.05 | 627.9 | 9,110,570.00 | 2,230,190.00 | 149.1 | 6,938,224.36 | New York |
| North Carolina | 21,014,450.41 | 8,746,454.59 | 1,119.8 | 2,583,206.80 | 1,061,531.74 | 67.1 | 8,484,390.26 | 3,596,828.11 | 202.5 | 1,790,503.65 | 897,253.57 | 35.0 | 1,715,137.99 | North Carolina |
| North Dakota | 10,829,263.82 | 5,268,930.47 | 1,917.5 | 706,567.83 | 353,098.37 | 157.3 | 4,386,760.51 | 2,195,294.70 | 540.2 | 850,366.72 | 425,183.26 | 106.8 | 2,506,152.20 | North Dakota |
| Ohio | 41,572,252.81 | 15,244,993.93 | 1,191.1 | 2,821,213.23 | 991,893.17 | 85.3 | 11,357,815.47 | 4,330,272.20 | 345.0 | 1,916,946.96 | 661,810.54 | 53.6 | 4,502,826.16 | Ohio |
| Oklahoma | 20,787,024.94 | 9,672,890.34 | 852.2 | 2,022,986.21 | 928,040.47 | 87.2 | 7,088,346.64 | 3,337,040.73 | 318.1 | 719,754.38 | 227,746.86 | 20.1 | 1,894,068.61 | Oklahoma |
| Oregon | 14,388,188.70 | 7,142,364.63 | 794.6 | 1,409,879.93 | 767,336.36 | 75.3 | 2,817,306.00 | 1,644,702.27 | 144.2 | 287,542.30 | 5,000.00 | 8.8 | 1,319,943.74 | Oregon |
| Pennsylvania | 43,054,835.19 | 16,222,023.97 | 850.3 | 4,442,508.99 | 1,319,739.45 | 80.9 | 35,763,416.09 | 9,714,045.47 | 661.6 | 1,347,522.21 | 383,823.01 | 25.7 | 3,899,149.10 | Pennsylvania |
| Rhode Island | 2,628,496.20 | 1,119,688.09 | 64.8 | 481,300.30 | 154,988.63 | 6.0 | 2,380,016.40 | 664,003.63 | 40.2 | 263,012.75 | 63,135.00 | 4.2 | 675,753.65 | Rhode Island |
| South Carolina | 11,163,347.84 | 5,121,267.54 | 1,235.9 | 1,161,737.54 | 412,561.25 | 58.6 | 6,019,404.94 | 2,829,823.87 | 345.2 | 1,882,341.79 | 544,985.88 | 76.1 | 892,885.46 | South Carolina |
| South Dakota | 12,091,434.67 | 5,989,879.00 | 1,447.9 | 1,949,197.66 | 945,729.32 | 246.7 | 6,266,539.22 | 2,948,508.81 | 895.6 | | | | 1,282,672.87 | South Dakota |
| Tennessee | 13,789,140.98 | 6,732,079.77 | 497.9 | 2,871,554.63 | 1,401,638.03 | 106.1 | 10,130,163.99 | 4,519,007.47 | 326.6 | 508,337.81 | 253,268.94 | 31.3 | 2,374,896.79 | Tennessee |
| Texas | 54,120,970.83 | 21,057,940.12 | 3,907.1 | 7,582,894.39 | 3,068,017.71 | 462.8 | 21,181,770.25 | 9,377,493.42 | 1,216.5 | 4,648,172.12 | 2,123,338.91 | 264.6 | 4,979,640.84 | Texas |
| Utah | 6,258,159.41 | 3,818,836.91 | 423.1 | 132,178.99 | 99,880.35 | 5.9 | 3,246,305.87 | 2,209,280.96 | 256.5 | 247,206.06 | 188,770.60 | 15.9 | 1,502,010.18 | Utah |
| Vermont | 3,015,174.51 | 1,458,894.45 | 107.8 | 200,295.47 | 100,082.03 | 3.5 | 1,981,542.29 | 884,137.49 | 46.2 | 59,192.10 | 29,596.05 | 0.1 | 801,796.98 | Vermont |
| Virginia | 13,099,720.01 | 6,271,998.20 | 676.2 | 5,898,146.03 | 2,888,237.33 | 212.7 | 6,158,415.87 | 2,703,907.73 | 208.1 | 1,080,542.11 | 375,834.90 | 32.9 | 1,481,535.84 | Virginia |
| Washington | 13,352,504.18 | 6,117,211.87 | 526.7 | 2,925,268.96 | 1,288,161.91 | 120.5 | 2,450,114.56 | 952,400.00 | 43.1 | 757,215.96 | 261,000.00 | 1.2 | 1,527,002.22 | Washington |
| West Virginia | 7,343,200.86 | 3,230,293.33 | 326.7 | 252,664.30 | 123,013.89 | 12.8 | 6,979,051.35 | 2,787,834.00 | 185.6 | 777,918.20 | 298,915.54 | 29.7 | 912,454.24 | West Virginia |
| Wisconsin | 21,807,140.91 | 8,919,640.62 | 1,451.7 | 848,974.42 | 419,006.01 | 45.7 | 5,813,723.15 | 2,859,492.42 | 280.8 | 194,866.35 | 97,041.00 | 15.3 | 5,143,634.95 | Wisconsin |
| Wyoming | 8,809,819.33 | 4,739,096.67 | 982.0 | 1,471,587.35 | 893,333.81 | 97.2 | 3,019,093.54 | 1,890,684.01 | 214.4 | 28,580.20 | 18,348.00 | | 1,024,811.51 | Wyoming |
| Hawaii | | | | | | | 342,277.22 | 97,440.00 | 6.5 | | | | 1,002,713.00 | Hawaii |
| TOTALS | 740,140,790.82 | 325,654,346.00 | 41,898.3 | 101,326,796.31 | 46,046,798.42 | 5,078.3 | 385,565,266.84 | 164,547,107.97 | 16,017.2 | 44,638,129.78 | 15,355,546.19 | 1,794.3 | 119,771,201.42 | TOTALS |

* Includes projects reported completed (final vouchers not yet paid) totaling: Estimated cost $ 121,452,493.52 Federal aid $ 53,262,865.48 Miles 5,039.2

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